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# Low Velocity Performance of Anemometers

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National Bureau of Standards  
Fluid Engineering Division  
Washington, D.C. 20234

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Final Report

on

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Evaluation of the Behavior of Mine Anemometers in the NBS Low  
Velocity Calibration Facility

Prepared for

**United States Department of the Interior  
Bureau of Mines**



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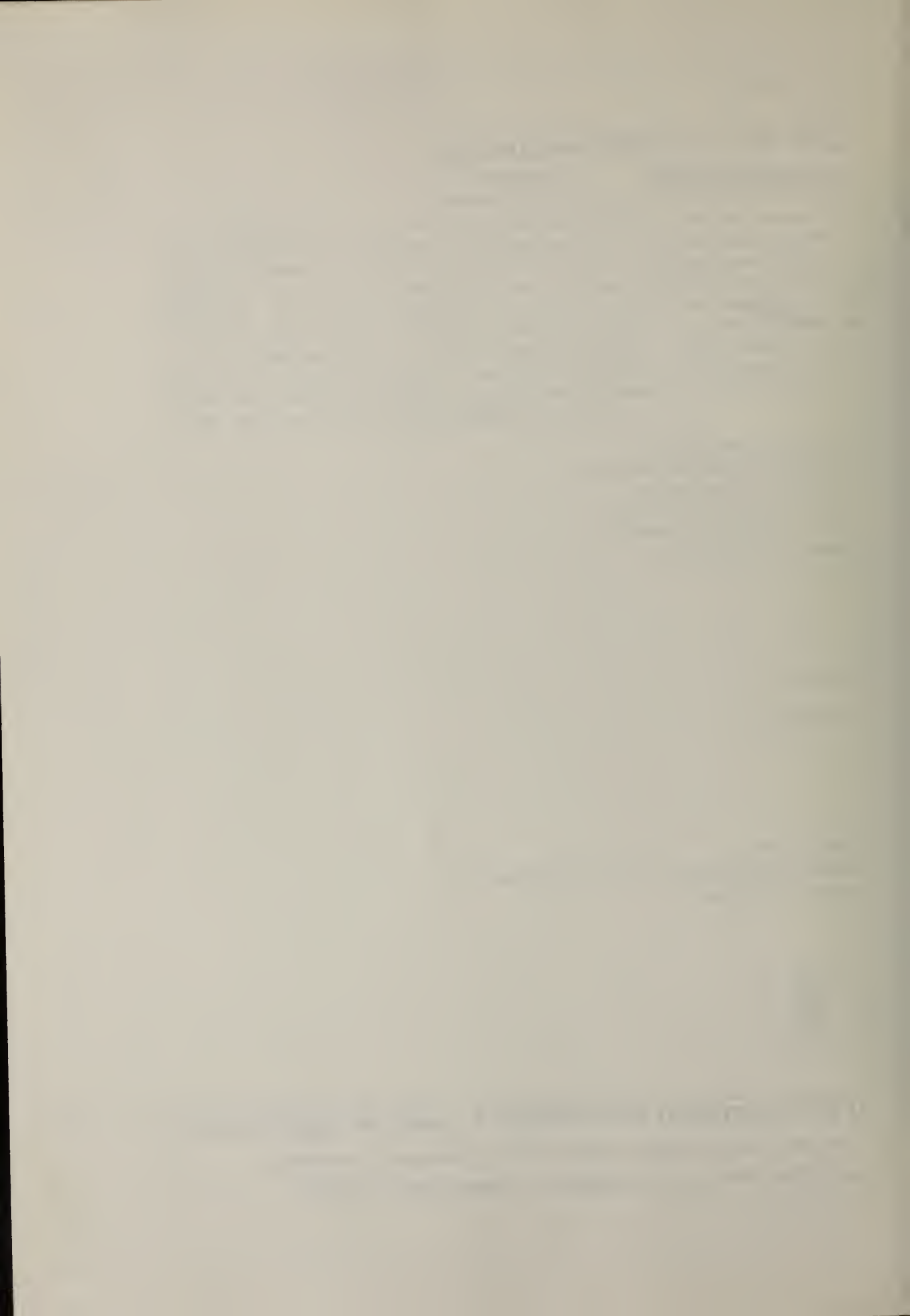


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## NOMENCLATURE

|             |   |
|-------------|---|
| $U$         | velocity measured by laser velocimeter standard                         |
| $U_i$       | velocity indicated by anemometer under test                             |
| $f$         | frequency output from (vortex-shedding) anemometer under test (Hz)      |
| $I$         | current output from (heated foil) anemometer under test ( $\mu A$ )     |
| $U_{if}$    | line segments fitted to $(U, U_i)$ , $(U, f)$ , or $(U, I)$ data        |
| $\bar{U}$   | group mean true velocity  |
| $\bar{U}_i$ | group mean indicated velocity   |
| $\bar{f}$   | group mean indicated frequency  |
| $\bar{I}$   | group mean indicated current  |
| $\sigma_i$  | standard deviation of $U_i$ data about $U_{if}$                         |
| $\sigma_f$  | standard deviation of $f$ data about $U_{if}$                           |
| $\sigma_I$  | standard deviation of $I$ data about $U_{if}$                           |
| $\sigma$    | $\sigma_i$ , $\sigma_f$ , or $\sigma_I$ divided by $dU_{if}/dU$         |
| $\sigma_c$  | $\sigma$ corrected for known variance in laser velocimeter measurements |
| $R_i$       | resolution of the instrument under test                                 |
| $R$         | resolution expressed as true velocity                                   |

## LOW VELOCITY PERFORMANCE OF ANEMOMETERS

### 1. INTRODUCTION

The National Bureau of Standards in order to meet the need for a calibration capability with adequate accuracy at low air velocities, i.e., below 2.5 meters per second, undertook the development of a low-velocity calibration facility for wind speed measuring instruments which would provide a capability down to 0.05 meters per second (approximately 10 feet per minute) with an accuracy of plus or minus one percent. It was a natural consequence therefore that when said facility became operational to undertake an evaluation of the state-of-the-art and to provide the information needed as to the reliability and performance of instrumentation for such measurement. Thus various types of instruments for low velocity air measurement have undergone testing at NBS. This report summarizes the results and presents analyses of the instruments' performance.

Performance is measured in terms of a comparison between indicated and true air speed, the variation in repeated measurements, and the minimum operating air speed. Since the indicated air speed may be easily corrected using a chart, for instance, to find the true air speed, the latter two measurements of performance are of primary interest. Thus a detailed handling of random error is presented including the effect of instrument resolution where necessary.

### 2. THE FACILITY

The data reported here were measured in the Low Velocity Air-flow Facility [1] at the National Bureau of Standards. The facility consists primarily of a low velocity wind tunnel and a laser velocimeter velocity standard. The wind tunnel (Figure 1) is an open return type with the fan pulling the air through the tunnel.

The test section, 6.1 m in length and nominally 0.91 m by 0.91 m in cross-section, is constructed of acrylic panels mounted in a steel frame. The test section is supported from above by I-beams to allow the laser velocimeter traversing gear, mounted on rails on the floor of the room parallel to the test section, to be positioned at any location along the length of the test section.

The performance of the wind tunnel in terms of steadiness, flatness of mean velocity profiles, and turbulence level is extremely satisfactory. No drift in air velocity during a test was detected. The mean velocity profiles outside of the wall boundary layers are flat to within 0.5% even as close as 1 meter from the entrance to the test section. The residual turbulence intensity is less than 0.05%.

A laser velocimeter is used as the velocity standard. It is linear with velocity from first principles and does not suffer a

severe loss of resolution at very low velocities as does, for instance, the Pitot-static tube. Furthermore, it is nonintrusive and has good spatial resolution. Adequate sensitivity is obtained in the facility without the artificial seeding of scattering particles. Thus the difficulties and inconvenience associated with seeding and the possible effect of such seeding on the performance of the device under test are avoided.

### 3. THE INSTRUMENTS

#### Instrument A -- Bronze bearing vane anemometer.

All of the vane anemometers tested have flat vanes without camber or twist as opposed to helicoidal types. All but one (instrument E below) are entirely mechanical and require only a timer (stopwatch) for operation.

Instrument A is a commercially available instrument (Davis Instrument Manufacturing Company, Incorporated, 4-Inch Low Speed Anemometer, S/N 22889).<sup>1</sup> It was supplied for test by the U. S. Mining Enforcement and Safety Administration (MESA) at the request of the U. S. Bureau of Mines. The housing is 4 inches (10.2 cm) in diameter and 1-3/4 inches (4.4 cm) deep (Figure 2). Thin metal vanes without camber or twist mounted on arms drive a rotor linked to a dial indicator by a gear train. The bearings in this particular instrument are standard bronze bearings (as opposed to ball bearings). One revolution on the dial represents an indicated passage of 100 feet of air through the instrument. Thus an external timer (not a part of the anemometer) is required to complete a measurement of velocity (an average velocity for the duration of the measurement).

#### Instrument B -- Ball bearing vane anemometer.

This anemometer is a commercially available instrument (Davis Instrument Manufacturing Company, Incorporated, 4-Inch Low Speed Anemometer, S/N 24323 B). It was supplied for test by the U. S. Mining Enforcement and Safety Administration (MESA) at the request of the U. S. Bureau of Mines. As may be seen in Figure 3, it is identical to instrument A except that the bearings are ball bearings instead of bronze bearings.

#### Instrument C -- Jewel bearing vane anemometer.

This anemometer is a commercially available instrument (Sybron/Taylor Corporation, 4-Inch Anemometer, S/N H873). It was supplied for test by the U. S. Mining Enforcement and Safety Administration (MESA) at the request of the U. S. Bureau of Mines. It is very

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<sup>1</sup>These particular instruments were selected as being representative of the type of anemometer and their selection does not represent an endorsement.

similar in appearance (Figure 4) to instruments A and B though the dimensions of the hub and shroud are slightly different. The bearings, however, are jewel instead of bronze or ball bearing.

Instrument D -- High speed vane anemometer.

This anemometer is a commercially available instrument (Davis Instrument Manufacturing Company, Incorporated, 4-Inch High Speed Anemometer, S/N 31125B). It was supplied for test by the U. S. Mining Enforcement and Safety Administration (MESA) at the request of the U. S. Bureau of Mines. This anemometer (Figure 5) is dimensionally identical to instrument B, including ball bearings, but has four vanes instead of eight, thus permitting operation at higher air speeds.

Instrument E -- Magnetic pick-up vane anemometer.

This anemometer is a commercially available instrument (Abbirko Instruments, Limited, Flowmaster, S/N 6184). It was supplied for test by the U. S. Mining Enforcement and Safety Administration at the request of the U. S. Bureau of Mines. The instrument's vane housing is approximately 2.75 inches (7.0 cm) in diameter (see Figure 6) with an attached block for the magnetic pick-up, or proximity transducer, and a handle projecting down from the block. The magnetic pick-up detects the passage of the metal vanes, and the resulting electrical signal is converted to a deflection of a meter connected to the probe by a cable. The meter was located outside the tunnel during the tests and was oriented horizontally. Three ranges of operation are selectable: low - 0 to 300 fpm, medium - 0 to 1000 fpm, and high - 0 to 3000 fpm. The anemometer requires a 9 volt battery for operation.

Instrument F -- Full size impact-deflection anemometer.

This type of anemometer operates from the dynamic pressure of the air stream. This pressure is converted to a deflection of a dial indicator by impacting a small vane linked to the meter. The operation is thus entirely mechanical.

Instrument F is a commercially available instrument (Alnor Instrument Company, Velometer, Series 6000-P). It was supplied for test by the U. S. Mining Enforcement and Safety Administration at the request of the U. S. Bureau of Mines. The instrument (Figure 7) consists of a main body meter (approximately 15 x 17 x 6 cm) with connections for one of several probes. The Pitot probe is composed of a cylinder 0.5 inches (1.27 cm) in diameter and 13 inches (33 cm) long which mounts in a range selector unit connected to the main body by hoses. The cylinder has ports to admit the airflow and must be properly oriented in the airstream to obtain a reading. The range selector may be set to one of two ranges, 100-1250 fpm (low range) and 100-2500 fpm (high range). Other range selectors are available,

but were not tested herein.

The diffuser probe (Figure 8) is similar to the Pitot probe except that only impact pressure is utilized in the diffuser probe thus requiring a vent to be opened in the range selector for operation. It operates over the same ranges as the Pitot probe.

The low velocity probe (Figure 9) attaches directly to the main body and operates like the Pitot probe except over a range of 30-300 fpm. Note that all the probes and the main body were mounted entirely within the wind tunnel since the flow is slightly below atmospheric pressure.

#### Instrument G -- Compact impact-deflection anemometer.

This anemometer is a commercially available instrument (Alnor Instrument Company, Velometer Jr., Type 8100). It was supplied for test by the U. S. Mining Enforcement and Safety Administration at the request of the U. S. Bureau of Mines. The instrument is approximately 8.2 x 10.2 x 3.8 cm in size (see Figure 10) and contains entrance and exit ports for the air on the upstream and downstream surfaces, respectively. The entrance port is adjustable (two sizes) providing two ranges of velocity measurement, 50 to 200 fpm and 100 to 800 fpm. The instrument is a one piece, self-contained unit.

#### Instruments H and I -- Vortex-Shedding Anemometers.

This type of instrument measures velocity by detecting the frequency of a vortex street shed from a bluff, two-dimensional object such as a cylinder. This frequency will be well-defined if the shedding body is properly matched to the air speed.

These anemometers (two units, serial numbers 49 and 48, respectively, are commercially available instruments (J-TEC Associates, Incorporated, VA-216 Air Draft Sensor)<sup>1</sup> supplied for test by the U. S. Bureau of Mines. The instruments are approximately 30 x 10 x 14 cm in size (see Figure 11) and include probe heads and the necessary electronics for operation. The probe head consists of a rod approximately 6.4 mm in diameter and 35 mm in length supported at the ends and oriented normal to the air stream. An ultrasonic transmitter and receiver pair located downstream of the cylinder detect the vortex street shed by the cylinder as an amplitude modulation of the ultrasonic signal. This modulation is converted by the electronics section to a pulse train (approximately a square wave signal) as an output. A frequency-to-voltage converter section also provides an analog output. Since the frequency of shedding of a vortex street is roughly proportional to velocity, the output signals can be used to measure the air velocity. A separate power supply is necessary to operate the instrument.

#### Instrument J -- Heated foil anemometer.

This anemometer is a prototype instrument (Thermogage, Inc.,

Air Velocity Meter) supplied for test by the U. S. Bureau of Mines. It consists of a tube approximately 9.5 mm in diameter and 10.2 cm in length aligned with the flow, and a 15.9 mm diameter handle attached normal to the tube midway along its length (see Figure 12). A part of the wall of the tube is composed of a heat-conducting foil which has an electrically heated spot flanked upstream and downstream by temperature sensors. As air passes through the tube, the upstream sensor experiences a lower temperature than the downstream sensor, and this difference, converted to an electrical signal, is related to velocity. The instrument thus consists of this thermal transducer and an electronics module containing a line-voltage operated power supply, the necessary circuitry, and a micro-ammeter.

#### 4. THE TESTS

##### 4.1 General Description

Many types of tests can be performed on various aspects of an instrument's performance, such as its response to turbulent flow, shock and vibration, dirt, moisture, or orientation to velocity and gravity vectors, but the results of such tests require comparison with a base level of performance. This base level should be obtained under conditions closely approximating the ideal environment, which, in the case of anemometers is a steady, uniform flow field of large dimensions. The Low Velocity Airflow Facility has been found to provide a good approximation to these conditions for the instruments reported on here.

The performance is measured in terms of the mean error, the random error, and minimum operating air speed. The mean error, for the purposes of this report, is defined simply to be the mean difference between the air speed indicated by the anemometer under test and the air speed indicated by the velocity standard. Random error is defined as usual in terms of a root-mean-square deviation of the indicated air speed from an appropriate mean value (see section 5 for more details). To permit evaluation of these characteristics, multiple calibration tests and minimum operating speed determinations were performed.

##### 4.2 Calibration tests

These tests consisted of measuring the response of the anemometer undergoing testing to an air flow of a speed measured by the laser velocimeter velocity standard. (See tables A-1 through J-5). Each instrument was tested at a number of air speeds over the range of operation below about 4 m/s. Five such tests were conducted for each instrument with an attempt made to repeat the air speeds for each test. (The effects of not exactly repeating the air speeds are discussed in the analysis of section 5). The particular test set-up for the calibrations varied somewhat from instrument to instrument, but in general consisted of mounting the anemometer on or near the centerline of the test-section, 1 m from its upstream end, locating the laser velocimeter probe volume at a position where disturbance of the flow due to the presence of the anemometer is negligible, and measuring the air speed with both the

anemometer under test and the laser velocimeter standard. The details which varied from instrument to instrument are described in the following paragraphs.

Four of the vane anemometers, A, B, C, and D, are so similar in dimension and function that the tests were nearly identical for them. The location of the probe volume (30 cm upstream of the anemometer) was the same for each and was determined from a series of velocity measurements upstream of instrument A. These are presented in Figure 13 as the ratio of the local velocity to the freestream velocity. These measurements were performed at two freestream speeds, 3.6 and 0.36 m/s to verify independence of freestream speed as predicted by potential flow theory. With no anemometer in the tunnel, variation in velocity along the centerline is imperceptible over the distance traversed.

The same four anemometers, A, B, C, and D, also require a timer to determine the indicated airspeed. This was computed from initial and final readings of the dial and of the associated time interval (around two minutes). The anemometer runs continuously in the tunnel since it cannot be accessed while the tunnel is in operation without disturbing the flow. Thus the readings of the anemometer were performed with the anemometer in operation. The laser velocimeter measurement of the air velocity was performed during the time interval for reading the vane anemometer.

The remaining vane anemometer, instrument E, has an electronic read-out, thus not requiring a separate time measurement. It is smaller in dimension than A through D and will disturb the airflow less. Consequently the probe volume could be located as for instruments A through D. As with the others, the laser velocimeter measurement of the air velocity was performed during the time interval for reading the vane anemometer.

The full size impact deflection anemometer, instrument F, has three velocity probes which were tested on all ranges. The Pitot probe and diffuser probes are essentially slender (1.27 cm diameter) cylinders presenting little disturbance to the flow. Thus they were tested with the probe volume located 30 cm upstream of the probe as with the vane anemometers. The meter body and hoses were located downstream of the probes. The low velocity probe, however, attaches directly to the meter body rather than by hoses, thus requiring the meter body and probe to be placed together at the calibration position. Thus the velocity upstream of this combination was measured to again find a location for the probe volume. However, 30 cm upstream was found to be quite sufficient (Figure 14).

The velocity upstream of the compact impact-deflection anemometer, instrument G, was also measured to find a location for the probe volume, and again 30 cm was found to be sufficient.

The vortex-shedding anemometers, instruments H and I, are larger than the others and disturb the flow proportionately more. However, it was found that by placing the measuring head on the centerline (thus with the bulk of the instrument off the centerline) that the laser velocimeter probe volume could be located 35 cm upstream of the instruments. Since the outputs of H and I are an analog voltage and a pulse train, separate instrumentation consisting of a digital volt meter and a frequency counter were required for the tests. These measurements were recorded during the time interval required for measurement by the laser velocimeter standard.

The remaining instrument, the heated foil anemometer, instrument J, has a very small probe head and was thus tested with the probe volume again at 30 cm upstream. The output is an analog meter reading in microamps.

#### 4.3 Minimum Operating Speed

Determination of the minimum air speed at which operation of an instrument is possible varies with the type of instrument under test. The instruments may be separated into two categories for this purpose: instruments that entirely cease to function below some speed, and instruments that lose sufficient resolution in their output (or read zero) below some speed.

The vane anemometers, A through E, all fit in the first category, but here two minimum operating speeds may be defined, a starting speed, the speed at which the instrument starts from rest as the air speed is slowly increased, and a stopping speed, the speed at which the anemometer ceases to turn as the air speed is slowly decreased.

To determine the starting speeds of the instruments, the velocity in the tunnel was increased from below the starting speed at a smooth acceleration of approximately 0.15 m/s/min until movement of the vanes could be detected by eye. At that moment the air velocity would be fixed and the laser velocimeter measurements initiated. If the anemometer continued rotating for at least thirty seconds and did not decelerate, the measurement of velocity by the laser velocimeter was recorded as the starting speed.

Because of the anemometer's angular momentum, stopping speed is more difficult to determine than starting speed. Some preliminary runs indicated that a two minute interval between reductions in air velocity of approximately 1 cm/s was sufficient for the anemometer to come to rest if the stopping speed had been reached.

The only other instruments having minimum speeds of functioning are the vortex-shedding anemometers, instruments H and I. As the air speed is reduced the depth of modulation of the ultrasonic signal is reduced until at some speed it can no longer be detected by the instruments.

Since neither friction nor angular momentum is involved, as opposed to the vane anemometers, the minimum operating speed was easily determined by simply observing the pulse train from the instruments as the air speed was slowly reduced. When the pulses disappeared (which occurred rather abruptly) the air speed was recorded as the minimum operating speed.

The other instruments, the impact pressure anemometers, F and G, and the heated foil anemometer, J, all fit in the second category of instruments which lose sufficient resolution below some speed. This minimum operating speed is defined here to be that at which the anemometer under test indicates a speed of one-half the lowest marked division on the dial above zero. This was chosen because at that indicated speed the resolution is at least as large as the reading.

## 5. RESULTS AND DISCUSSION

### 5.1 Methods of data analysis

As may be observed in Figures 16 through 32, the data for the calibration curves are in groups because of attempts to repeat the true air speeds from run to run. The mean calibration data are defined to be the pairs of values consisting of the mean true velocity for a group and the mean indicated velocity (or frequency, etc.) of that group. Plots of these pairs (connected by solid lines in Figures 16 through 32), give an indication of linearity of the instrument's response and serve in determining the random error of that response. Furthermore, the mean data may be used to define calibration curves for correcting an indicated reading in the field. Figures 33 through 59 (odd numbered) are especially valuable in this respect.

Random error is frequently defined as the standard deviation (about the mean) of repeated measurements. This is only useful, however, if the true or reference value is fixed or has negligible variation from measurement to measurement. Precise repetition of wind tunnel speeds, though, is extremely difficult at the low speeds required for these tests. The random error here, then is defined in terms of the root-mean-square deviation of the data in a group from an appropriate curve through that group. This is illustrated in Figure 15 where  $\bar{U}$  is the group mean true velocity and  $\bar{U}_i$  is the group mean indicated velocity. An ideal calibration curve,  $U_i(U)$ , is approximated within the group by a straight line segment,  $U_{if}$ , passing through  $(\bar{U}, \bar{U}_i)$ . The root-mean-square deviation, curve,  $\bar{U}_i(U)$ , is approximated within the group by a straight line segment,  $U_{if}$ , passing through  $(\bar{U}, \bar{U}_i)$ . The root-mean-square deviation,  $\sigma_i$ , of the data,  $(U_r, U_{ir})$  from  $\bar{U}_i(U)$  is thus approximated by the root-mean-square deviation from the line segment,  $U_{if}$ . More specifically:

$$\sigma_i^2 \approx \frac{1}{N} \sum_{r=1}^N [U_{ir} - U_{if}(U_{ir})]^2$$

The slope of the line segment,  $U_{if}$ , is computed as the average of the slopes of line segments connecting the  $(\bar{U}, \bar{U}_i)$  of interest with the  $(\bar{U}, \bar{U}_i)$ 's of the neighboring group(s).

The standard deviation,  $\sigma_i$ , is a measure of the scatter in the data in terms of indicated air speed (or frequency, etc., depending on the measurement). To compare instruments, however, this must be converted to an equivalent scatter in true air speed. An approach consistent with the above approximations for  $\sigma_i$  is to divide  $\sigma_i$  by the local slope of  $U_{if}$ , namely  $(dU_{if}/dU)$ . The result,  $\sigma$ , is now taken to be a measure of the random error of the instrument in terms of true velocity, subject to the corrections and limitations discussed below.

Computing  $\sigma_i$  from measurements by an instrument having a scale with a resolution,  $R_i$ , much smaller than  $\sigma_i$  is an accepted procedure for determining repeatability of the instrument. However, if the resolution is large (poor) compared to  $\sigma_i$  (where  $\sigma_i$  is presumed known by some means independent of the scale being considered, say by a second scale with better resolution), the indicated  $\sigma$  may be much smaller than it should be. For a Gaussian distribution of errors it is assumed that  $\sigma_i$  may be adequately computed if the resolution is at most approximately twice  $\sigma_i$ .

As with the computed values of  $\sigma_i$ , these values of resolution,  $R_i$ , were converted to equivalent values,  $R$ , in terms of true velocity by dividing by the slope  $(dU_{if}/dU)$ . These latter values, divided by two, were then included in the figures where applicable in units of velocity or as percentage of  $U$ . As will be seen,  $R/2$  does indeed exceed  $\sigma$  for several of the instruments. Thus these particular values of  $\sigma$  should be taken with reservation and perhaps replaced by the values  $R/2$ . The performance of the instrument in these instances in terms of random error may exceed the quality of its resolution.

The above analysis presumes that the contribution to the random errors from the laser velocimeter is negligible, and indeed this is true for most of the tests. The random uncertainty of the laser velocimeter (random error) may be estimated from repeated measurements at a particular fan setting, thus also including any unsteadiness in the air speed. The value of this uncertainty was reduced as improvements were made to the laser system and varied from 0.005U for instruments A and B to 0.002U for instrument C to 0.001U for all the others. A corrected standard deviation for the tested instruments,  $\sigma_c$ , may thus be computed from, for instance,

$$\sigma_c^2 = \sigma^2 - (0.001U)^2$$

for any given  $U$ . Values of  $\sigma_c$  are included in the figures where they differ perceptibly from the values of  $\sigma$ . Since  $\pm 2\sigma_c$  is close to the 95 percent confidence interval for one measurement, curves of  $\pm 2\sigma_c$  are also included in the figures of  $U_i$  against  $U$ .

## 5.2 Calibration Data

The calibration data is presented in three forms for those instruments (A through G) that read directly in velocity: indicated versus true velocity, the deviation of indicated from true velocity against indicated velocity, and the percent deviation against true

velocity (Figures 16 through 60). Instruments H, I, and J have only plots of indicated output (frequency for H and I; current for J) against true velocity, Figures 30, 31, and 32. The primary function of the figures showing indicated velocity or output against true velocity is to illustrate the overall character of the response and the 95% confidence intervals. The other types of figures detail the features of most interest: the linearity, the range of scatter, and the deviation of indicated from the true velocity.

Vane anemometers A, B, and D are nearly identical in dimension and also have very similar calibration curves (see Figures 16, 18, 19, 33 through 36, 39, and 40). The rapid rise in the curve of Figure 33 as the velocity is reduced below 100 feet per minute (0.5 m/s) is almost certainly due to the appearance of friction effects since this instrument, A, has bronze bearings rather than ball bearings as do instruments B and D.

Instrument C, though a vane anemometer similar in appearance to A, B, and D, does differ somewhat from them, especially in the size and shape of the hub. This may explain the somewhat different character of the calibration data as presented in Figures 18, 37, and 38, though the instruments A, B, C, and D really all have quite similar calibration characteristics.

The magnetic pick-up transducer and associated electronics of instrument E may be the fundamental cause of the somewhat different character of its calibration data (figures 20, 21, 22, and 41 through 46) as compared to A through D. This is evidenced by the change in the data between ranges on the instrument (e.g., Figures 41 and 43). This cannot be caused by the dynamics of the vane since mechanically and aerodynamically the instrument is unchanged when compared at the same speed but on different ranges. The overall character of the calibrations though is not significantly different from those of A through D.

The characteristics of the calibration data for the impact-deflection type instruments, F and G, are determined by the aerodynamic characteristics of the probes and flow passages in the instruments as well as the meter characteristics. The different responses in the data of Figures 23 through 29, and 47 through 60 show the effect of various probes and ranges. The only major conclusion to be drawn at this point is that at the lower velocities it is usually very important because of large errors to use a good calibration correction method (chart or table, etc.) when making a measurement. This is true for all the instruments, A through G.

There is little to comment upon concerning the calibration curves for the vortex-shedding and heated film anemometers (H, I, and J) since the output is not "velocity." Both the principle of vortex street frequency-to-velocity relationship and the temperature-to-velocity relationship have long been known. These particular instruments have utilized these principles so that sufficient

sensitivity to velocity changes is produced. Both the near linearity of the vortex frequency with velocity and the usual non-linearity of the heat transfer to velocity are apparent in the data (Figures 30, 31, and 32).

### 5.3 Random Error

The random error, defined in Section 5.1, is presented in essentially two forms: in units of velocity, and as percent of group mean true velocity. The exceptions are instruments H, I, and J which do not read out in velocity and thus also have plots of random error in units of their read-out (frequency or current). As was discussed in Section 5.1, the measure of random error,  $\sigma$ , is in terms of true velocity which was produced by dividing  $\sigma_i$  by  $(d\bar{U}_i/d\bar{U})$ . The random error for the instruments not having direct read-out in velocity was also expressed in this manner by dividing the random error in terms of the readout ( $f$  or  $I$ ) by the group mean slope of the calibration curve ( $df/d\bar{U}$  or  $dI/d\bar{U}$ ).

The rather small sample size, five runs, causes a sizeable uncertainty in any one value of the random error. This is ameliorated somewhat though by the many values of velocity at which the random error was computed, thus permitting a smoothing of the data and effective reduction in the uncertainty. The data as presented, however, have not been smoothed but are the values computed according to the procedures presented in Section 5.1.

The data for vane anemometers A, B, C, and D (Figures 61 and 62 for A, 63 and 64 for B, 65 and 66 for C, and 67 and 68 for D) all show the same trends of  $\sigma$  and  $\sigma/\bar{U}$  with  $\bar{U}$  differing only in magnitude. The quite different character of the random error for instrument E, the only one with a magnetic pick-up transducer, Figures 69 and 74, is most likely associated with the effects of resolution as discussed in Section 5.1. As noted in the figures, the computed  $\sigma$  is frequently less than the value  $R/2$ . The other vane anemometers did not have random errors the same order as the resolution. For evaluation, as noted in Section 5.1, instrument E should perhaps have  $\sigma$  replaced by  $R/2$  for those values of  $\sigma$  less than  $R/2$ .

The impact-deflection type anemometers, instruments F and G, likewise have random errors exceeded by the values  $R/2$  at some air speeds (Figures 75 through 88). None of E, F, or G, however, show any adverse or highly unusual characteristics in the trends of the random error with velocity.

The effect of resolution on the vortex-shedding anemometers, instruments H and I, was eliminated by selecting instrumentation for reading the frequency which had far better resolution than required. This was possible in the laboratory because of the unprocessed signals, a pulse train and a voltage, available from

the instruments under test. The only slightly unusual feature of the results (Figures 89 through 96) was that for instrument H,  $\sigma_f/\bar{f}$  or  $\sigma/\bar{U}$  were nearly constant with velocity. Instrument I, though, gave values which increased somewhat as velocity was decreased. Since the instruments are nominally identical, no explanation is apparent for the (slight) variation.

The heated foil anemometer, instrument J, showed trends with velocity similar to A through D, but had resolution almost perfectly matched to the random error (Figures 97 through 100).

#### 5.4 Minimum Operating Speed

As discussed in Section 4.3, the minimum operating speed is determined in different ways for different instruments. The vane anemometers and the vortex-shedding anemometers all have minimum operating speeds determined by a complete ceasing of operation. The others simply lose resolution below some air speed. The various minimum operating speeds are summarized in Table K.

The difference in starting and stopping speeds for the vane anemometers, A through E, is due to the difference in static and dynamic friction factors for the bearings. Both speeds, though, are lower for the instruments with the more friction-free bearings, such as B and D. Instrument D, having fewer vanes than B, can operate at higher air speeds, but this advantage is offset somewhat by a decreased torque at lower speeds and thus a higher minimum operating speed.

Since the minimum operating speed of the vortex-shedding anemometers, instruments H and I, depends on the level of detection of the ultrasonic modulation, the difference in the speeds for these two instruments is probably due to slightly differing adjustments of the electronic detection circuits rather than a physical or aerodynamic difference. As noted in Section 4.3, these instruments ceased operating rather abruptly as speed was reduced, thus giving a well-defined minimum operating speed.

For the instruments having a minimum operating speed defined by resolution, namely F, G, and J, the procedure for specifying the speed is defined in Section 4.3, and the results are summarized in Table K. The only comment on the results is that the resolution as discussed in Section 4.3 is  $R_i$ , the indicated resolution, whereas the minimum operating speeds (for all the instruments) are true speeds.

#### 6. SUMMARY

Performance of ten anemometers of several different types has been measured at low air speeds in a wind tunnel which provides a steady air flow of low turbulence. Multiple calibration runs on

each instrument provided sufficient data for measuring performance in terms of random error about the mean calibration curve as well as the difference between the indicated and true speeds. Measurements were also performed of the minimum operating speeds of the anemometers.

The results are presented in both tabular and graphical form. A detailed description is included of the tests, the results, and the methods of analysis.

## 7. REFERENCES

1. L. P. Purtell and P. S. Klebanoff, A Low Velocity Airflow Calibration and Research Facility, NBS TN 989, 1979.

Table A1  
Davis Vane Anemometer  
Serial No. 22889

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 730.0                       | 679.0                  |
| 730.0                       | 687.0                  |
| 208.0                       | 208.0                  |
| 479.0                       | 458.0                  |
| 67.8                        | 94.2                   |
| 21.0                        | 76.2                   |
| 26.4                        | 75.0                   |
| 28.8                        | 72.0                   |
| 63.6                        | 94.2                   |
| 63.0                        | 89.4                   |

T = 18.8 to 20.0 °C  
B = 763.1 mm Hg

Table A2  
Davis Vane Anemometer  
Serial No. 22889

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 732.0                       | 679.0                  |
| 208.0                       | 208.0                  |
| 478.0                       | 451.0                  |
| 67.2                        | 91.8                   |
| 37.8                        | 73.2                   |
| 37.2                        | 65.4                   |
| 28.8                        | 64.8                   |
| 60.0                        | 90.0                   |
| 63.6                        | 91.2                   |

T = 20.1 to 21.0 °C  
B = 763.1 mm Hg

Table A3  
Davis Vane Anemometer  
Serial No. 22889

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 732.0                       | 690.0                  |
| 211.0                       | 207.0                  |
| 482.0                       | 458.0                  |
| 70.2                        | 94.8                   |
| 39.3                        | 72.0                   |
| 36.5                        | 73.2                   |
| 29.6                        | 76.2                   |
| 69.6                        | 96.0                   |
| 68.4                        | 96.6                   |

T = 21.0 °C  
B = 755.0 mm Hg

Table A4  
Davis Vane Anemometer  
Serial No. 22889

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 735.0                       | 687.0                  |
| 210.0                       | 214.0                  |
| 481.0                       | 460.0                  |
| 69.6                        | 94.2                   |
| 39.1                        | 75.6                   |
| 44.0                        | 76.8                   |
| 45.3                        | 75.6                   |
| 70.8                        | 96.6                   |
| 70.8                        | 96.6                   |

T = 21.6 °C  
B = 764.0 mm Hg

Table A5  
Davis Vane Anemometer  
Serial No. 22889

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 710.0                       | 688.0                  |
| 208.0                       | 215.0                  |
| 479.0                       | 458.0                  |
| 67.8                        | 95.4                   |
| 25.8                        | 74.4                   |
| 39.1                        | 74.4                   |
| 40.9                        | 75.0                   |
| 64.8                        | 94.2                   |

T = 21.6 °C  
B = 764.0 mm Hg



Table B1  
Davis Vane Anemometer  
Serial No. 24323 B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 712                         | 692                    |
| 205                         | 211                    |
| 466                         | 455                    |
| 80.4                        | 93.0                   |
| 56.5                        | 72.0                   |
| 33.2                        | 50.4                   |
| 12.4                        | 30.3                   |
| 23.1                        | 40.8                   |
| 5.8                         | 24.0                   |

T = 20.9 to 21.0 °C  
B = 745.7 mm Hg

Table B2  
Davis Vane Anemometer  
Serial No. 24323 B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 752                         | 724                    |
| 218                         | 224                    |
| 491                         | 484                    |
| 85.6                        | 99.3                   |
| 60.8                        | 73.1                   |
| 37.1                        | 51.1                   |
| 14.3                        | 29.6                   |
| 24.8                        | 40.6                   |
| 6.8                         | 23.0                   |
| 151                         | 158                    |

T = 21.7 to 21.9 °C  
B = 744.8 mm Hg

Table B5  
Davis Vane Anemometer  
Serial No. 24323 B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 717                         | 690                    |
| 206                         | 209                    |
| 468                         | 458                    |
| 80.5                        | 94.4                   |
| 57.5                        | 71.1                   |
| 35.0                        | 51.5                   |
| 12.2                        | 30.7                   |
| 22.7                        | 41.7                   |
| 8.1                         | 26.4                   |
| 144                         | 150                    |

T = 21.3 °C  
B = 747.1 mm Hg

Table B4  
Davis Vane Anemometer  
Serial No. 24323 B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 715                         | 696                    |
| 206                         | 215                    |
| 469                         | 466                    |
| 80.3                        | 96.0                   |
| 56.8                        | 72.0                   |
| 33.1                        | 50.4                   |
| 12.3                        | 31.2                   |
| 22.4                        | 41.4                   |
| 6.4                         | 25.2                   |
| 142                         | 152                    |

T = 22.1 °C  
B = 750.5 mm Hg

Table B5  
Davis Vane Anemometer  
Serial No. 24323 B

Indicated Air Speed,  
fpm

718  
207  
471  
78.8  
56.0

33.8  
13.6  
26.9  
11.5  
114

True Air Speed,  
fpm

682  
212  
461  
97.2  
70.8

50.4  
32.2  
43.4  
29.5  
153

T = 22.5 °C  
B = 750.5 mm Hg



Table C1  
Taylor Vane Anemometer  
Serial No. H873

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 722                         | 752                    |
| 589                         | 619                    |
| 457                         | 494                    |
| 309                         | 322                    |
| 190                         | 221                    |
| 110                         | 145                    |
| 56.8                        | 100                    |
| 26.7                        | 76.2                   |
| 7.1                         | 60.6                   |
| 27.1                        | 76.2                   |

T = 22.8 °C  
B = 751.2 mm Hg

Table C2  
Taylor Vane Anemometer  
Serial No. H873

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 719                         | 746                    |
| 589                         | 623                    |
| 454                         | 498                    |
| 324                         | 360                    |
| 190                         | 222                    |
| 109                         | 142                    |
| 55.8                        | 98.0                   |
| 25.1                        | 74.6                   |
| 8.4                         | 64.8                   |
| 25.7                        | 76.0                   |

T = 22.6 °C  
B = 753.5 mm Hg

Table C3  
Taylor Vane Anemometer  
Serial No. H873

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 720                         | 750                    |
| 588                         | 622                    |
| 456                         | 495                    |
| 323                         | 363                    |
| 190                         | 222                    |
| 110                         | 143                    |
| 54.7                        | 96.9                   |
| 23.4                        | 74.2                   |
| 3.8                         | 63.0                   |
| 23.8                        | 74.3                   |

T = 22.6 °C  
B = 753.1 mm Hg

Table C4  
Taylor Vane Anemometer  
Serial No. H873

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 723                         | 752                    |
| 590                         | 622                    |
| 458                         | 499                    |
| 324                         | 361                    |
| 190                         | 221                    |
| 110                         | 142                    |
| 54.9                        | 97.1                   |
| 22.4                        | 73.6                   |
| 23.0                        | 72.4                   |

T = 22.7 °C  
B = 752.9 mm Hg

Table C5  
Taylor Vane Anemometer  
Serial No. H873

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 721                         | 742                    |
| 588                         | 624                    |
| 457                         | 496                    |
| 323                         | 360                    |
| 190                         | 220                    |
| 109                         | 141                    |
| 54.5                        | 96.4                   |
| 20.0                        | 72.6                   |
| 8.5                         | 65.5                   |
| 20.8                        | 72.5                   |
| 9.8                         | 66.1                   |

T = 22.8 °C  
B = 753.0 mm Hg



Table D1  
Davis Vane Anemometer  
Serial No. 31125B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 785                         | 736                    |
| 639                         | 606                    |
| 496                         | 478                    |
| 359                         | 347                    |
| 219                         | 217                    |
| 136.4                       | 141.2                  |
| 80.2                        | 92.1                   |
| 53.7                        | 68.2                   |
| 38.9                        | 56.6                   |
| 28.6                        | 47.7                   |

T = 23.6 °C  
B = 753.8 mm Hg

Table D2  
Davis Vane Anemometer  
Serial No. 31125B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 786                         | 741                    |
| 640                         | 608                    |
| 497                         | 477                    |
| 358                         | 348                    |
| 219                         | 218                    |
| 137.3                       | 141.7                  |
| 81.8                        | 93.1                   |
| 56.1                        | 70.2                   |
| 41.8                        | 58.8                   |
| 26.4                        | 47.3                   |

T = 23.8 °C  
B = 753.8 mm Hg

Table D3  
Davis Vane Anemometer  
Serial No. 31125B

| Indicated Air speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 786                         | 738                    |
| 641                         | 608                    |
| 498                         | 477                    |
| 358                         | 347                    |
| 218                         | 216                    |
| 135.5                       | 139.5                  |
| 81.1                        | 91.5                   |
| 53.7                        | 68.0                   |
| 38.9                        | 55.7                   |
| 24.5                        | 43.4                   |

T = 24.2 °C  
B = 753.8 mm Hg

Table D4  
Davis Vane Anemometer  
Serial No. 31125B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 787                         | 738                    |
| 641                         | 608                    |
| 498                         | 477                    |
| 359                         | 347                    |
| 220                         | 217                    |
| 135.6                       | 140.5                  |
| 80.6                        | 91.4                   |
| 53.0                        | 67.7                   |
| 37.8                        | 55.4                   |
| 24.8                        | 44.6                   |

T = 24.6 °C  
B = 753.8 mm Hg

Table D5  
Davis Vane Anemometer  
Serial No. 31125B

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 786                         | 740                    |
| 641                         | 608                    |
| 498                         | 476                    |
| 357                         | 347                    |
| 219                         | 217                    |
| 134.6                       | 140.0                  |
| 81.0                        | 91.4                   |
| 52.6                        | 67.1                   |
| 38.3                        | 55.3                   |
| 27.1                        | 46.3                   |

T = 24.7 °C  
B = 753.2 mm Hg



Table E1  
 Abbirko Flowmaster  
 S/N 6184  
 Low Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 50  | 59.9  |
| 52  | 64.1  |
| 64  | 74.5  |
| 74  | 86.1  |
| 86  | 97.2  |
| 96  | 108.4 |
| 144 | 157   |
| 184 | 200   |
| 228 | 248   |
| 272 | 300   |

T = 20.8°C  
 B = 758.4 mm Hg

Table E2  
 Abbirko Flowmaster  
 S/N 6184  
 Low Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 50  | 59.6  |
| 54  | 64.0  |
| 64  | 74.0  |
| 76  | 86.4  |
| 86  | 97.1  |
| 98  | 108.8 |
| 144 | 157   |
| 186 | 200   |
| 228 | 250   |
| 274 | 299   |

T = 20.8°C  
 B = 758.4 mm Hg

Table E3  
 Abbirko Flowmaster  
 S/N 6184  
 Low Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 52                       | 59.8                |
| 54                       | 64.1                |
| 64                       | 74.3                |
| 76                       | 86.2                |
| 86                       | 96.7                |
| 98                       | 107.8               |
| 144                      | 157                 |
| 184                      | 199                 |
| 230                      | 249                 |
| 274                      | 298                 |

T = 20.9°C  
 B = 758.4 mm Hg

Table E4  
 Abbirko Flowmaster  
 S/N 6184  
 Low Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 48                       | 54.9                |
| 50                       | 60.0                |
| 60                       | 72.1                |
| 74                       | 82.8                |
| 84                       | 94.4                |
| 98                       | 106.8               |
| 142                      | 155                 |
| 184                      | 198                 |
| 228                      | 248                 |
| 272                      | 299                 |

T = 22.2°C  
 B = 750.3 mm Hg

Table E5  
Abbirko Flowmaster  
S/N 6184  
Low Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 50  | 56.6  |
| 52  | 60.7  |
| 60  | 72.1  |
| 76  | 84.2  |
| 84  | 95.3  |
| 98  | 106.4 |
| 142 | 155   |
| 182 | 199   |
| 228 | 249   |
| 272 | 298   |

T = 22.3°C  
B = 751.1 mm Hg

Table E6  
Abbirko Flowmaster  
S/N 6184  
Medium Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 30  | 63.4  |
| 55  | 86.1  |
| 75  | 108.1 |
| 170 | 199   |
| 265 | 299   |
| 370 | 402   |
| 475 | 507   |
| 585 | 611   |
| 685 | 716   |

T = 20.8°C  
B = 758.4 mm Hg

Table E7  
 Abbirko Flowmaster  
 S/N 6184  
 Medium Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 25                       | 64.4                |
| 55                       | 86.1                |
| 80                       | 108.2               |
| 170                      | 200                 |
| 270                      | 298                 |
| 375                      | 401                 |
| 480                      | 507                 |
| 585                      | 612                 |
| 685                      | 716                 |

T = 20.9°C  
 B = 758.4 mm Hg

Table E8  
 Abbirko Flowmaster  
 S/N 6184  
 Medium Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 25                       | 59.9                |
| 50                       | 82.8                |
| 75                       | 106.2               |
| 165                      | 199                 |
| 265                      | 298                 |
| 370                      | 402                 |
| 475                      | 506                 |
| 580                      | 611                 |
| 685                      | 714                 |

T = 22.2°C  
 B = 750.0 mm Hg

Table E9  
 Abbirko Flowmaster  
 S/N 6184  
 Medium Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 25  | 61.1  |
| 50  | 83.6  |
| 80  | 107.5 |
| 170 | 199   |
| 265 | 299   |
| 375 | 402   |
| 485 | 506   |
| 585 | 611   |
| 690 | 716   |

T = 22.3°C  
 B = 750.8 mm Hg

Table E10  
 Abbirko Flowmaster  
 S/N 6184  
 Medium Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 25  | 61.2  |
| 50  | 83.0  |
| 75  | 106.8 |
| 170 | 199   |
| 265 | 299   |
| 375 | 402   |
| 480 | 506   |
| 585 | 611   |
| 685 | 717   |

T = 22.4°C  
 B = 751.2 mm Hg

Table E11  
 Abbirko Flowmaster  
 S/N 6184  
 High Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 80                       | 107.4               |
| 170                      | 199                 |
| 270                      | 298                 |
| 370                      | 401                 |
| 480                      | 506                 |
| 580                      | 612                 |
| 690                      | 711                 |

T = 20.6°C  
 B = 758.4 mm Hg

Table E12  
 Abbirko Flowmaster  
 S/N 6184  
 High Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 90                       | 108.6               |
| 170                      | 199                 |
| 270                      | 299                 |
| 380                      | 403                 |
| 480                      | 507                 |
| 590                      | 613                 |
| 690                      | 716                 |

T = 20.9°C  
 B = 758.4 mm Hg

Table E13  
 Abbirko Flowmaster  
 S/N 6184  
 High Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 90                       | 106.3               |
| 180                      | 198                 |
| 280                      | 299                 |
| 380                      | 401                 |
| 490                      | 505                 |
| 590                      | 612                 |
| 695                      | 712                 |

$T = 22.1^{\circ}\text{C}$   
 $B = 750.0 \text{ mm Hg}$

Table E14  
 Abbirko Flowmaster  
 S/N 6184  
 High Range

| Indicated Air Speed, fpm | True Air Speed, fpm |
|--------------------------|---------------------|
| 90                       | 106.7               |
| 180                      | 199                 |
| 280                      | 299                 |
| 380                      | 403                 |
| 490                      | 507                 |
| 590                      | 611                 |
| 695                      | 715                 |

$T = 22.3^{\circ}\text{C}$   
 $B = 751.1 \text{ mm Hg}$

Table E15  
Abbirko Flowmaster  
S/N 6184  
High Range

Indicated Air Speed, fpm

True Air Speed, fpm

|     |       |
|-----|-------|
| 80  | 107.9 |
| 180 | 200   |
| 280 | 299   |
| 390 | 403   |
| 490 | 506   |
| 590 | 612   |
| 695 | 715   |

T = 22.4°C  
B = 751.2 mm Hg

Table F1  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 100                         | 102                    |
| 140                         | 153                    |
| 190                         | 198                    |
| 285                         | 297                    |
| 380                         | 400                    |
| 468                         | 498                    |
| 560                         | 603                    |
| 645                         | 705                    |

T = 21.1 °C  
 B = 739.5 mm Hg

Table F2  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 100                         | 102                    |
| 140                         | 154                    |
| 190                         | 199                    |
| 280                         | 297                    |
| 378                         | 400                    |
| 468                         | 499                    |
| 558                         | 604                    |
| 645                         | 705                    |

T = 21.1 °C  
 B = 739.5 mm Hg

Table F3  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 100                         | 102                    |
| 140                         | 153                    |
| 190                         | 198                    |
| 280                         | 297                    |
| 380                         | 401                    |
| 470                         | 498                    |
| 560                         | 605                    |
| 645                         | 706                    |

T = 21.8 °C  
 B = 740.1 mm Hg

Table F4  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 100                         | 102                    |
| 140                         | 153                    |
| 188                         | 198                    |
| 285                         | 297                    |
| 378                         | 401                    |
| 468                         | 498                    |
| 560                         | 603                    |
| 645                         | 704                    |

T = 21.8 °C  
 B = 740.1 mm Hg

Table F5  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 100                         | 102                    |
| 140                         | 153                    |
| 192                         | 198                    |
| 285                         | 297                    |
| 378                         | 402                    |
| 470                         | 497                    |
| 560                         | 602                    |
| 648                         | 709                    |

T = 21.8 °C  
 B = 741.0 mm Hg

Table F6  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 75                          | 103                    |
| 125                         | 149                    |
| 190                         | 201                    |
| 300                         | 300                    |
| 410                         | 399                    |
| 540                         | 502                    |
| 645                         | 604                    |
| 760                         | 705                    |

T = 21.1 °C  
 B = 749.2 mm Hg

Table F7  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 75                          | 103                    |
| 130                         | 149                    |
| 190                         | 200                    |
| 295                         | 299                    |
| 420                         | 399                    |
| 540                         | 503                    |
| 655                         | 604                    |
| 755                         | 707                    |

T = 21.1 °C  
 B = 749.2 mm Hg

Table F8  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 80                          | 103                    |
| 130                         | 149                    |
| 195                         | 200                    |
| 300                         | 300                    |
| 435                         | 399                    |
| 540                         | 503                    |
| 650                         | 606                    |
| 755                         | 706                    |

T = 21.1 °C  
 B = 749.3 mm Hg

Table F9  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 80                          | 103                    |
| 135                         | 149                    |
| 185                         | 200                    |
| 305                         | 300                    |
| 425                         | 399                    |
| 540                         | 503                    |
| 645                         | 605                    |
| 750                         | 704                    |

T = 21.1 °C  
 B = 749.3 mm Hg

Table F10  
 Alnor Velometer  
 Series 6000-P  
 Pitot probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 75                          | 103                    |
| 125                         | 149                    |
| 190                         | 200                    |
| 300                         | 300                    |
| 420                         | 398                    |
| 540                         | 503                    |
| 650                         | 605                    |
| 755                         | 705                    |

T = 21.1 °C  
 B = 749.3 mm Hg

Table F11  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 75                          | 101                    |
| 145                         | 148                    |
| 230                         | 201                    |
| 395                         | 301                    |
| 540                         | 401                    |
| 675                         | 501                    |
| 820                         | 602                    |
| 940                         | 701                    |

T = 21.1 °C  
 B = 747.8 mm Hg

Table F12  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 75                          | 101                    |
| 145                         | 149                    |
| 240                         | 200                    |
| 395                         | 301                    |
| 545                         | 401                    |
| 680                         | 503                    |
| 815                         | 602                    |
| 940                         | 698                    |

T = 21.1 °C  
 B = 747.8 mm Hg

Table F13  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 80                          | 101                    |
| 145                         | 149                    |
| 245                         | 200                    |
| 400                         | 301                    |
| 540                         | 401                    |
| 680                         | 499                    |
| 820                         | 601                    |
| 940                         | 699                    |

T = 21.1 °C  
 B = 747.5 mm Hg

Table F14  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 90                          | 101                    |
| 150                         | 147                    |
| 240                         | 201                    |
| 395                         | 301                    |
| 545                         | 400                    |
| 675                         | 501                    |
| 825                         | 600                    |
| 945                         | 698                    |

T = 21.1 °C  
 B = 747.5 mm Hg

Table F15  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-2500 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 90                          | 101                    |
| 150                         | 148                    |
| 245                         | 200                    |
| 395                         | 301                    |
| 540                         | 400                    |
| 680                         | 500                    |
| 815                         | 599                    |
| 940                         | 698                    |

T = 21.1 °C  
 B = 747.3 mm Hg

Table F16  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 135                         | 101                    |
| 195                         | 149                    |
| 280                         | 199                    |
| 395                         | 300                    |
| 510                         | 401                    |
| 620                         | 498                    |
| 735                         | 601                    |
| 840                         | 698                    |

T = 21.1 °C  
 B = 746.0 mm Hg

Table F17  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 130                         | 101                    |
| 200                         | 148                    |
| 278                         | 198                    |
| 398                         | 299                    |
| 515                         | 399                    |
| 620                         | 498                    |
| 738                         | 599                    |
| 840                         | 699                    |

T = 21.1 °C  
 B = 746.0 mm Hg

Table F18  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 130                         | 102                    |
| 200                         | 149                    |
| 278                         | 199                    |
| 400                         | 300                    |
| 515                         | 401                    |
| 620                         | 500                    |
| 740                         | 602                    |
| 840                         | 697                    |

T = 21.1 °C  
 B = 745.4 mm Hg

Table F19  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 135                         | 101                    |
| 200                         | 149                    |
| 278                         | 200                    |
| 398                         | 301                    |
| 515                         | 402                    |
| 618                         | 501                    |
| 738                         | 601                    |
| 843                         | 701                    |

T = 21.1 °C  
 B = 745.4 mm Hg

Table F20  
 Alnor Velometer  
 Series 6000-P  
 Diffuser probe-1250 Scale

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 138                         | 101                    |
| 200                         | 148                    |
| 275                         | 199                    |
| 395                         | 301                    |
| 518                         | 401                    |
| 620                         | 499                    |
| 738                         | 603                    |
| 840                         | 696                    |

T = 20.6 °C  
 B = 744.3 mm Hg

Table F21  
 Alnor Velometer  
 Series 6000-P  
 Low Velocity probe

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 33                          | 43.0                   |
| 47                          | 56.5                   |
| 68                          | 77.6                   |
| 93                          | 102                    |
| 145                         | 150                    |
| 207                         | 199                    |
| 297                         | 271                    |

T = 20.6 °C  
 B = 742.5 mm Hg

Table F22  
 Alnor Velometer  
 Series 6000-P  
 Low Velocity probe

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 33                          | 42.9                   |
| 45                          | 56.5                   |
| 66                          | 77.4                   |
| 94                          | 101                    |
| 145                         | 150                    |
| 207                         | 199                    |
| 296                         | 272                    |

T = 20.6 °C  
 B = 742.5 mm Hg

Table F23  
 Alnor Velometer  
 Series 6000-P  
 Low Velocity probe

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 32                          | 42.6                   |
| 46                          | 56.1                   |
| 67                          | 77.6                   |
| 92                          | 101                    |
| 146                         | 149                    |
| 207                         | 199                    |
| 295                         | 270                    |

T = 20.0 °C  
 B = 742.0 mm Hg

Table F24  
 Alnor Velometer  
 Series 6000-P  
 Low Velocity probe

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 34                          | 42.9                   |
| 45                          | 55.8                   |
| 68                          | 77.3                   |
| 93                          | 101                    |
| 144                         | 149                    |
| 208                         | 198                    |
| 295                         | 271                    |

T = 20.0 °C  
 B = 742.0 mm Hg

Table F25  
Alnor Velometer  
Series 6000-P  
Low Velocity probe

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 33                          | 42.3                   |
| 48                          | 56.9                   |
| 68                          | 77.6                   |
| 94                          | 102                    |
| 144                         | 149                    |
| 207                         | 199                    |
| 296                         | 272                    |

T = 20.0 °C  
B = 740.3 mm Hg

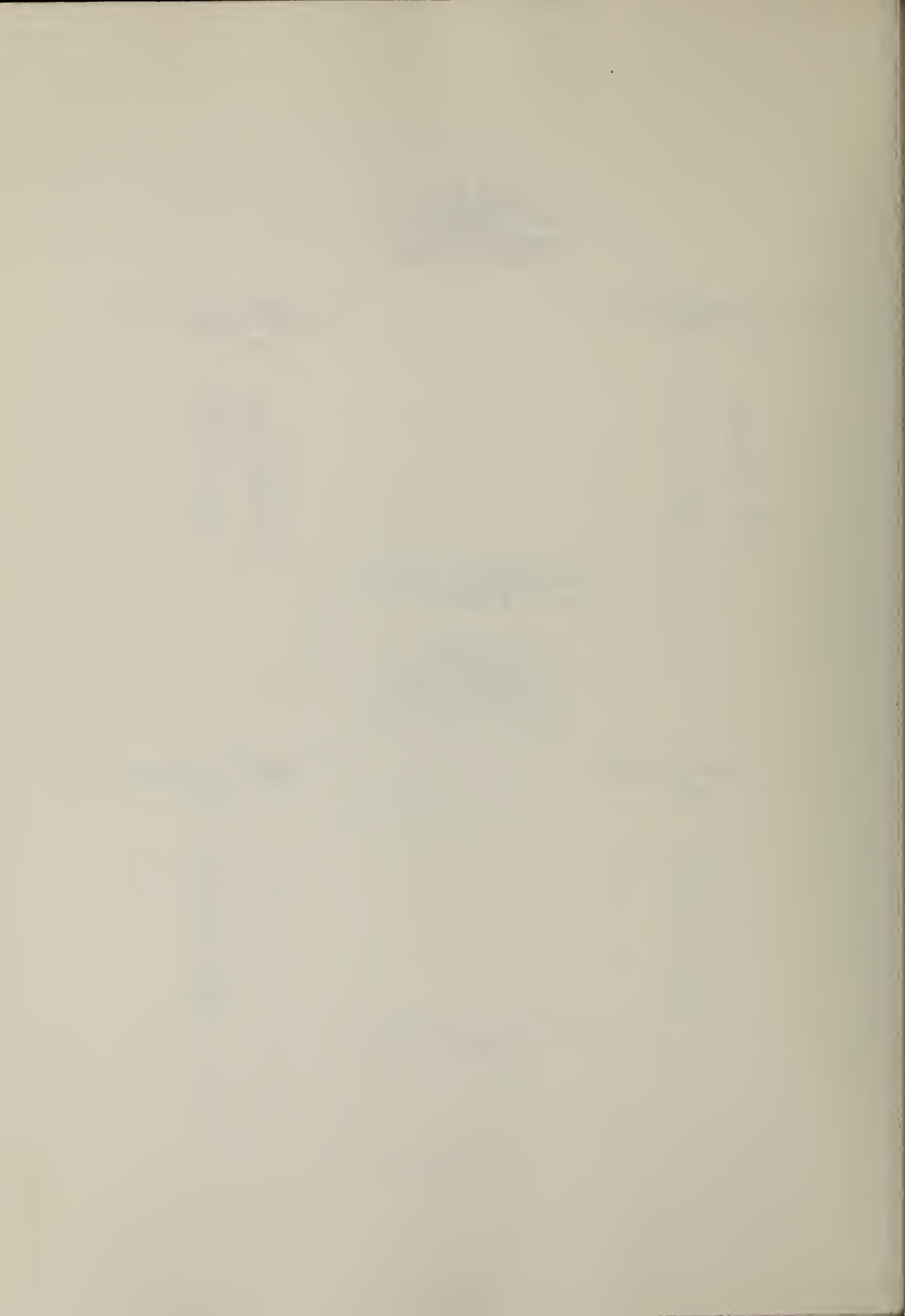


Table G1  
Alnor Velometer Jr.  
Low Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 205                         | 204.7                  |
| 172                         | 166.4                  |
| 148                         | 141.1                  |
| 122                         | 116.3                  |
| 100                         | 93.0                   |
| 80                          | 70.6                   |
| 62                          | 53.0                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G2  
Alnor Velometer Jr.  
Low Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 205                         | 204.6                  |
| 170                         | 165.8                  |
| 146                         | 141.6                  |
| 122                         | 118.0                  |
| 100                         | 94.9                   |
| 78                          | 70.3                   |
| 60                          | 53.2                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G3  
Alnor Velometer Jr.  
Low Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 200                         | 204.2                  |
| 170                         | 166.6                  |
| 148                         | 142.1                  |
| 120                         | 117.0                  |
| 100                         | 92.7                   |
| 80                          | 70.7                   |
| 62                          | 53.3                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G4  
Alnor Velometer Jr.  
Low Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 205                         | 204.7                  |
| 170                         | 166.3                  |
| 146                         | 141.1                  |
| 120                         | 116.4                  |
| 100                         | 92.9                   |
| 80                          | 69.5                   |
| 62                          | 53.4                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G5  
Alnor Velometer Jr.  
Low Range

Indicated Air Speed,  
fpm

True Air Speed,  
fpm

203  
170  
146  
122  
102

204.6  
166.2  
141.3  
117.5  
93.6

80  
62

70.1  
53.4

$T = 27.0^{\circ}\text{C}$   
 $B = 747.5 \text{ mm Hg}$

Table G6  
Alnor Velometer Jr.  
High Range

Indicated Air Speed,  
fpm

True Air Speed,  
fpm

775  
600  
525  
480  
420

712.8  
608.5  
503.1  
399.0  
296.1

300  
230  
195  
160  
100

192.2  
142.0  
117.2  
93.5  
50.8

$T = 26.9^{\circ}\text{C}$   
 $B = 747.5 \text{ mm Hg}$

Table G7  
Alnor Velometer Jr.  
High Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 800                         | 714.7                  |
| 610                         | 608.8                  |
| 525                         | 504.2                  |
| 485                         | 400.0                  |
| 420                         | 296.5                  |
| 300                         | 192.4                  |
| 230                         | 141.7                  |
| 195                         | 117.4                  |
| 160                         | 93.3                   |
| 105                         | 52.5                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G8  
Alnor Velometer Jr.  
High Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 800                         | 714.2                  |
| 610                         | 609.7                  |
| 530                         | 504.9                  |
| 480                         | 399.3                  |
| 420                         | 296.9                  |
| 300                         | 191.8                  |
| 210                         | 140.3                  |
| 180                         | 117.4                  |
| 150                         | 93.0                   |
| 100                         | 53.3                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G9.  
Alnor Velometer Jr.  
High Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 800                         | 715.9                  |
| 610                         | 609.4                  |
| 530                         | 504.4                  |
| 480                         | 400.2                  |
| 415                         | 296.9                  |
| 300                         | 192.5                  |
| 230                         | 141.5                  |
| 195                         | 116.9                  |
| 160                         | 93.4                   |
| 100                         | 52.8                   |

T = 26.9 °C  
B = 747.5 mm Hg

Table G10  
Alnor Velometer Jr.  
High Range

| Indicated Air Speed,<br>fpm | True Air Speed,<br>fpm |
|-----------------------------|------------------------|
| 800                         | 715.7                  |
| 625                         | 610.6                  |
| 530                         | 504.6                  |
| 480                         | 399.0                  |
| 420                         | 296.3                  |
| 300                         | 191.5                  |
| 225                         | 141.0                  |
| 195                         | 115.4                  |
| 160                         | 92.3                   |
| 100                         | 54.4                   |

T = 27.0 °C  
B = 747.5 mm Hg

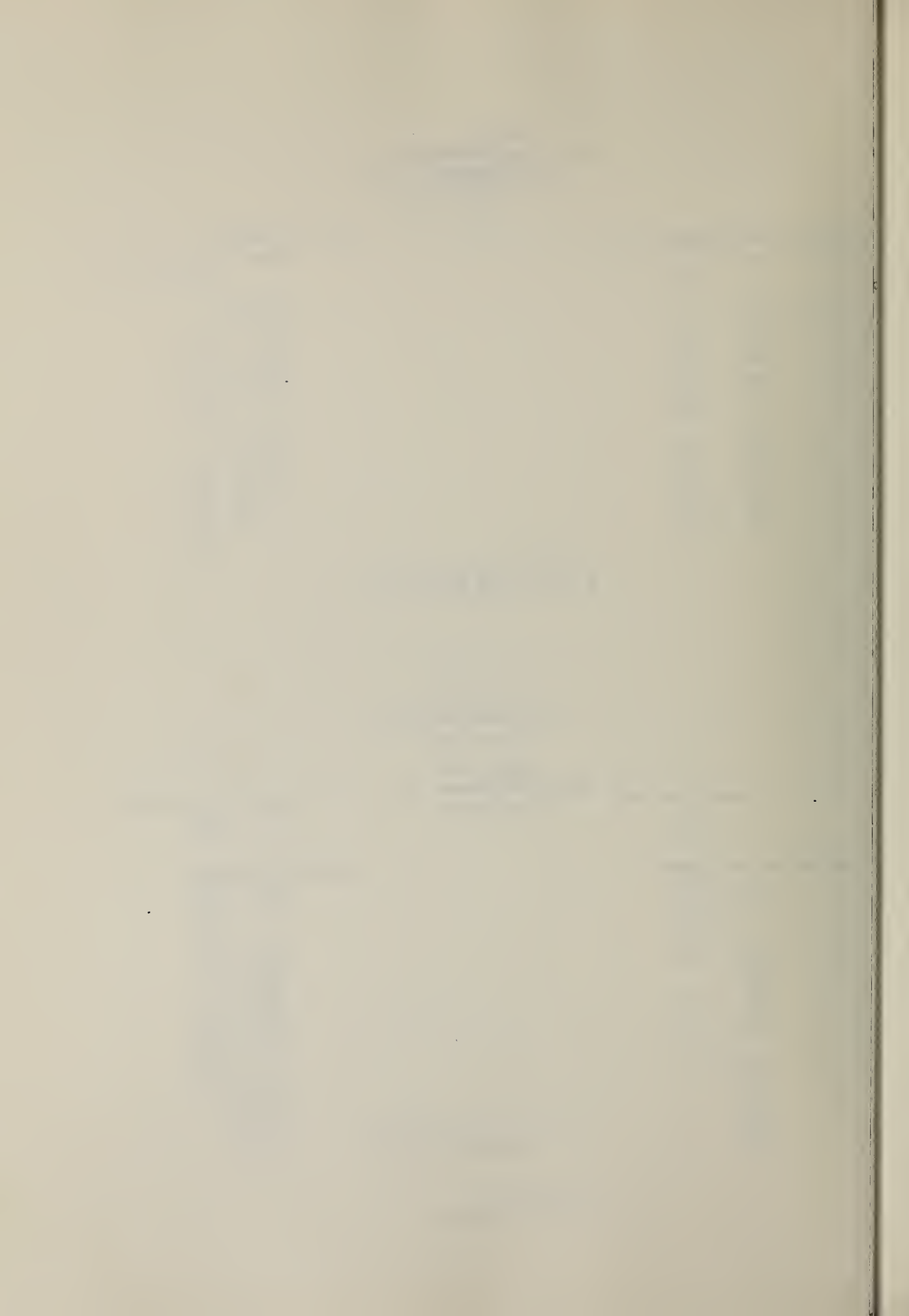


Table H1  
J-Tec Type VA-216  
S/N 49

| Instrument Output Frequency<br>Hz | Instrument Output Voltage<br>volts | True Air Speed<br>fpm |
|-----------------------------------|------------------------------------|-----------------------|
| 8.68                              | .132                               | 60.3                  |
| 10.9                              | .160                               | 72.2                  |
| 12.6                              | .182                               | 81.0                  |
| 14.6                              | .208                               | 91.4                  |
| 16.5                              | .233                               | 100.6                 |
| 22.7                              | .312                               | 128                   |
| 32.5                              | .44                                | 170                   |
| 46.9                              | .62                                | 219                   |
| 65.4                              | .88                                | 284                   |
| 83.2                              | 1.12                               | 374                   |
| 110                               | 1.48                               | 492                   |
| 147                               | 1.95                               | 649                   |
| 187                               | 2.45                               | 835                   |
| 242                               | 3.20                               | 1103                  |
| 278                               | 3.70                               | 1290                  |
| 318                               | 4.20                               | 1495                  |

T = 21.3 to 21.6 °C

B = 752.4 mm Hg

Table H2  
J-Tec Type VA-216  
S/N 49

| Instrument Output Frequency<br>Hz | Instrument Output Voltage<br>volts | True Air Speed<br>fpm |
|-----------------------------------|------------------------------------|-----------------------|
| 8.63                              | .126                               | 60.8                  |
| 10.5                              | .154                               | 72.5                  |
| 12.3                              | .175                               | 81.6                  |
| 15.0                              | .209                               | 92.9                  |
| 16.6                              | .229                               | 100.8                 |
| 22.9                              | .308                               | 130                   |
| 32.6                              | .44                                | 172                   |
| 46.9                              | .62                                | 220                   |
| 66.2                              | .86                                | 284                   |
| 84.0                              | 1.13                               | 375                   |
| 112                               | 1.49                               | 492                   |
| 148                               | 1.95                               | 647                   |
| 186                               | 2.50                               | 833                   |
| 245                               | 3.20                               | 1109                  |
| 276                               | 3.65                               | 1293                  |
| 320                               | 4.15                               | 1502                  |

T = 22.5 °C

B = 752.7

Table H3  
J-Tec Type VA-216  
S/N 49

| Instrument Output Frequency<br>Hz | Instrument Output Voltage<br>volts | True Air Speed<br>fpm |
|-----------------------------------|------------------------------------|-----------------------|
| 8.70                              | .130                               | 61.6                  |
| 10.8                              | .154                               | 72.5                  |
| 12.7                              | .180                               | 81.6                  |
| 14.9                              | .210                               | 92.5                  |
| 16.3                              | .226                               | 100.2                 |
| 23.0                              | .311                               | 131                   |
| 32.6                              | .43                                | 171                   |
| 47.4                              | .60                                | 219                   |
| 65.4                              | .86                                | 285                   |
| 84.0                              | 1.13                               | 375                   |
| 112                               | 1.48                               | 492                   |
| 147                               | 1.96                               | 648                   |
| 186                               | 2.47                               | 834                   |
| 245                               | 3.21                               | 1110                  |
| 282                               | 3.68                               | 1298                  |
| 318                               | 4.16                               | 1497                  |

T = 22.5 to 22.8 °C

B = 752.8 mm Hg

Table H4  
J-Tec Type VA-216  
S/N 49

| Instrument Output Frequency<br>Hz | Instrument Output Voltage<br>volts | True Air Speed<br>fpm |
|-----------------------------------|------------------------------------|-----------------------|
| 8.59                              | .126                               | 59.8                  |
| 10.6                              | .154                               | 71.1                  |
| 12.6                              | .175                               | 80.5                  |
| 14.8                              | .209                               | 91.9                  |
| 16.3                              | .227                               | 100.4                 |
| 22.7                              | .308                               | 131                   |
| 32.7                              | .43                                | 171                   |
| 46.7                              | .60                                | 219                   |
| 64.9                              | .86                                | 286                   |
| 82.6                              | 1.12                               | 374                   |
| 110                               | 1.48                               | 493                   |
| 148                               | 1.97                               | 648                   |
| 189                               | 2.46                               | 835                   |
| 243                               | 3.20                               | 1106                  |
| 279                               | 3.65                               | 1286                  |
| 316                               | 4.19                               | 1505                  |

T = 22.8 to 23.0 °C

B = 752.8 mm Hg

Table H5  
J-Tec Type VA-216  
S/N 49

| Instrument Output Frequency<br>Hz | Instrument Output Voltage<br>volts | True Air Speed<br>fpm |
|-----------------------------------|------------------------------------|-----------------------|
| 8.50                              | .126                               | 59.5                  |
| 10.8                              | .152                               | 71.5                  |
| 12.6                              | .177                               | 80.9                  |
| 14.9                              | .207                               | 92.1                  |
| 16.4                              | .226                               | 100.2                 |
| 23.3                              | .313                               | 130                   |
| 32.8                              | .43                                | 172                   |
| 46.5                              | .61                                | 220                   |
| 65.4                              | .84                                | 284                   |
| 83.3                              | 1.12                               | 375                   |
| 110                               | 1.48                               | 490                   |
| 147                               | 1.96                               | 648                   |
| 188                               | 2.47                               | 836                   |
| 244                               | 3.20                               | 1111                  |
| 279                               | 3.65                               | 1292                  |
| 320                               | 4.12                               | 1502                  |

T = 23.2 to 23.4 °C

B = 751.3 mm Hg

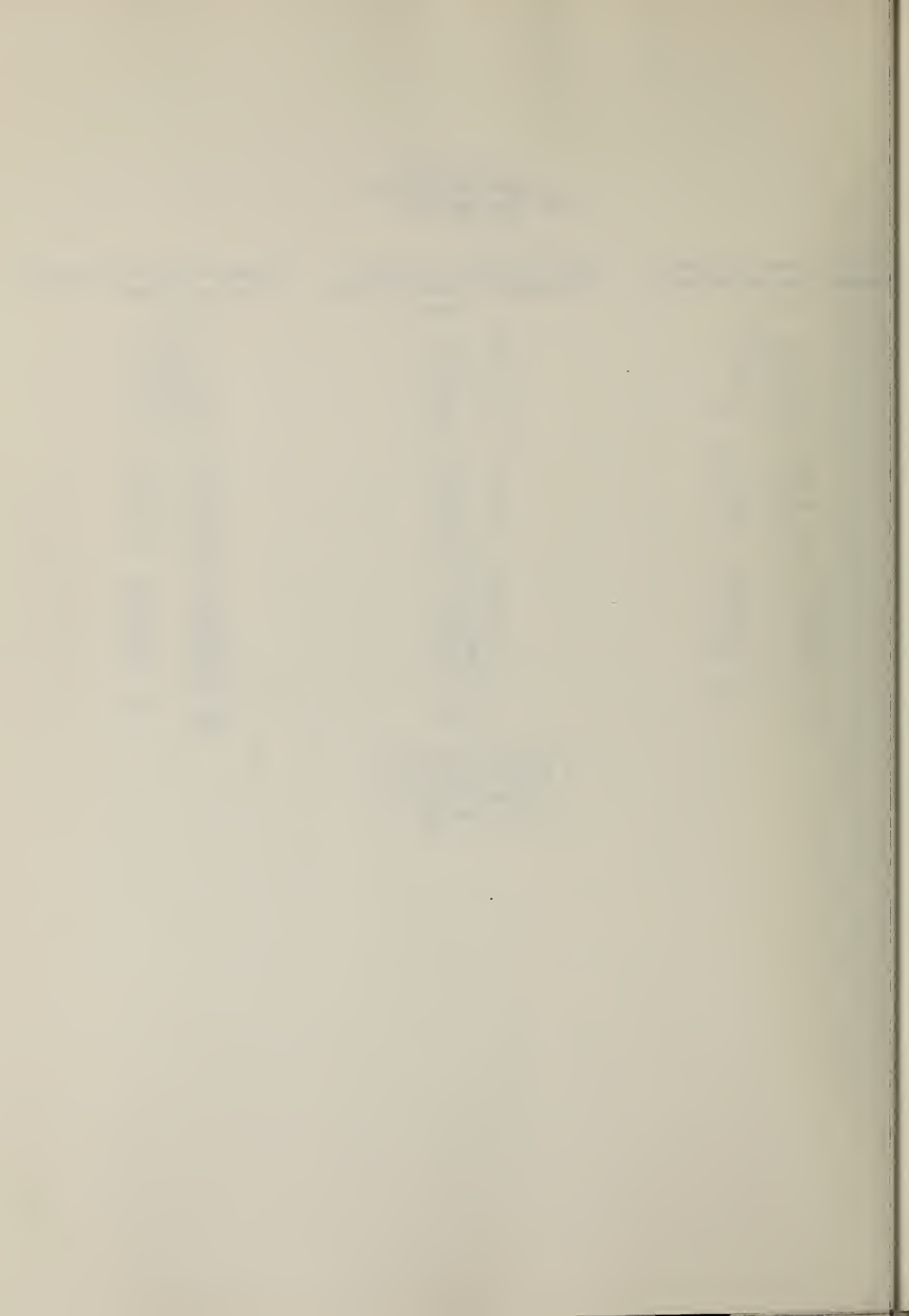


Table II  
J-Tec Type VA-216  
S/N 48

| Instrument Output Frequency,<br>Hz | Instrument Output Voltage,<br>volts | True Air Speed,<br>fpm |
|------------------------------------|-------------------------------------|------------------------|
| 8.61                               | .118                                | 59.6                   |
| 10.8                               | .146                                | 71.0                   |
| 12.6                               | .168                                | 80.4                   |
| 14.7                               | .195                                | 92.0                   |
| 16.3                               | .216                                | 100.5                  |
| 22.2                               | .29                                 | 130                    |
| 30.8                               | .40                                 | 172                    |
| 46.3                               | .60                                 | 220                    |
| 59.5                               | .78                                 | 286                    |
| 82.6 .                             | 1.09                                | 375                    |
| 106.8                              | 1.43                                | 494                    |
| 145.6                              | 1.91                                | 650                    |
| 185.2                              | 2.44                                | 832                    |

T = 23.1°C  
B = 751.0 mm Hg

Table I2  
J-Tec Type VA-216  
S/N 48

| Instrument Output Frequency,<br>Hz | Instrument Output Voltage,<br>volts | True Air Speed,<br>fpm |
|------------------------------------|-------------------------------------|------------------------|
| 8.48                               | .116                                | 58.1                   |
| 10.7                               | .144                                | 70.3                   |
| 12.5                               | .166                                | 80.2                   |
| 15.0                               | .199                                | 93.0                   |
| 16.2                               | .215                                | 99.5                   |
| 22.2                               | .295                                | 130                    |
| 29.7                               | .39                                 | 170                    |
| 46.1                               | .60                                 | 219                    |
| 57.5                               | .76                                 | 285                    |
| 82.0                               | 1.09                                | 375                    |
| 105.7                              | 1.42                                | 494                    |
| 144.5                              | 1.92                                | 649                    |
| 186.2                              | 2.45                                | 835                    |

T = 23.4°C  
B = 751.2 mm Hg

Table I3  
J-Tec Type VA-216  
S/N 48

| Instrument Output Frequency,<br>Hz | Instrument Output Voltage,<br>volts | True Air Speed,<br>fpm |
|------------------------------------|-------------------------------------|------------------------|
| 8.65                               | .117                                | 59.6                   |
| 10.9                               | .147                                | 71.9                   |
| 12.7                               | .169                                | 81.0                   |
| 15.0                               | .198                                | 92.9                   |
| 16.4                               | .218                                | 100.9                  |
| 23.0                               | .29                                 | 130                    |
| 29.2                               | .38                                 | 171                    |
| 45.7                               | .60                                 | 220                    |
| 57.8                               | .77                                 | 285                    |
| 80.0                               | 1.07                                | 375                    |
| 106.4                              | 1.49                                | 492                    |
| 143.7                              | 1.91                                | 650                    |
| 184.8                              | 2.45                                | 836                    |

T = 23.7°C

B = 750.8 mm Hg

Table I4  
J-Tec Type VA-216  
S/N 48

| Instrument Output Frequency,<br>Hz | Instrument Output Voltage,<br>volts | True Air Speed,<br>fpm |
|------------------------------------|-------------------------------------|------------------------|
| 8.50                               | .119                                | 63.5                   |
| 10.6                               | .142                                | 71.2                   |
| 12.5                               | .166                                | 80.1                   |
| 14.7                               | .196                                | 91.8                   |
| 16.3                               | .217                                | 100.2                  |
| 21.5                               | .28                                 | 130                    |
| 28.8                               | .38                                 | 170                    |
| 45.2                               | .59                                 | 220                    |
| 59.9                               | .78                                 | 284                    |
| 78.1                               | 1.04                                | 375                    |
| 107.0                              | 1.40                                | 492                    |
| 143.5                              | 1.90                                | 647                    |
| 186.2                              | 2.44                                | 834                    |

T = 23.9°C

B = 750.2 mm Hg

Table I5  
J-Tec Type VA-216  
S/N 48

| Instrument Output Frequency,<br>Hz | Instrument Output Voltage,<br>volts | True Air Speed,<br>fpm |
|------------------------------------|-------------------------------------|------------------------|
| 8.40                               | .06                                 | 63.6                   |
| 10.6                               | .142                                | 70.4                   |
| 12.4                               | .165                                | 80.0                   |
| 14.6                               | .195                                | 91.1                   |
| 16.2                               | .215                                | 99.4                   |
| 22.7                               | .30                                 | 130                    |
| 27.9                               | .37                                 | 170                    |
| 44.8                               | .59                                 | 219                    |
| 60.2                               | .77                                 | 283                    |
| 78.1                               | 1.04                                | 375                    |
| 103.7                              | 1.58                                | 489                    |
| 142.9                              | 1.88                                | 642                    |
| 184.8                              | 2.43                                | 834                    |

T = 24.2°C  
B = 750.2 mm Hg



Table J1

## Thermogage Air Velocity Meter

| Instrument Output,<br>ua | True Air Speed,<br>fpm |
|--------------------------|------------------------|
| 99                       | 138.7                  |
| 89                       | 119.2                  |
| 80                       | 101.8                  |
| 70                       | 85.4                   |
| 58                       | 70.0                   |
| 44                       | 54.8                   |
| 27                       | 39.2                   |
| 16                       | 27.9                   |
| 9                        | 22.1                   |
| 8                        | 17.7                   |

T = 22.2 °C

B = 752.8 mm Hg

Table J2

## Thermogage Air Velocity Meter

| Instrument Output,<br>ua | True Air Speed,<br>fpm |
|--------------------------|------------------------|
| 100                      | 138.7                  |
| 91                       | 119.1                  |
| 81                       | 102.7                  |
| 70                       | 86.4                   |
| 58                       | 69.8                   |
| 45                       | 54.7                   |
| 26                       | 37.5                   |
| 18                       | 30.4                   |
| 11                       | 23.4                   |
| 7                        | 15.8                   |

T = 22.2 °C

B = 752.8 mm Hg

Table J3

## Thermogage Air Velocity Meter

| Instrument Output,<br>ua | True Air Speed,<br>fpm |
|--------------------------|------------------------|
| 99                       | 137.9                  |
| 90                       | 119.1                  |
| 81                       | 102.7                  |
| 70                       | 86.3                   |
| 58                       | 70.0                   |
| 44                       | 54.3                   |
| 26                       | 38.2                   |
| 18                       | 29.8                   |
| 11                       | 23.0                   |
| 9                        | 20.1                   |

T = 22.2 °C

B = 752.8 mm Hg

Table J4

## Thermogage Air Velocity Meter

| Instrument Output,<br>ua | True Air Speed,<br>fpm |
|--------------------------|------------------------|
| 100                      | 138.6                  |
| 90                       | 118.9                  |
| 81                       | 101.8                  |
| 71                       | 86.5                   |
| 58                       | 69.5                   |
| 43                       | 53.6                   |
| 24                       | 35.6                   |
| 17                       | 28.7                   |
| 12                       | 23.6                   |
| 8                        | 19.4                   |

T = 22.2 °C

B = 752.8 mm Hg

Table J5

## Thermogage Air Velocity Meter

| Instrument Output,<br>ua | True Air Speed,<br>fpm |
|--------------------------|------------------------|
| 99                       | 140.0                  |
| 91                       | 119.1                  |
| 82                       | 102.2                  |
| 69                       | 85.0                   |
| 57                       | 68.4                   |
| 43                       | 52.9                   |
| 27                       | 35.7                   |
| 18                       | 29.9                   |
| 11                       | 21.7                   |
| 9                        | 18.6                   |

T = 22.0 °C

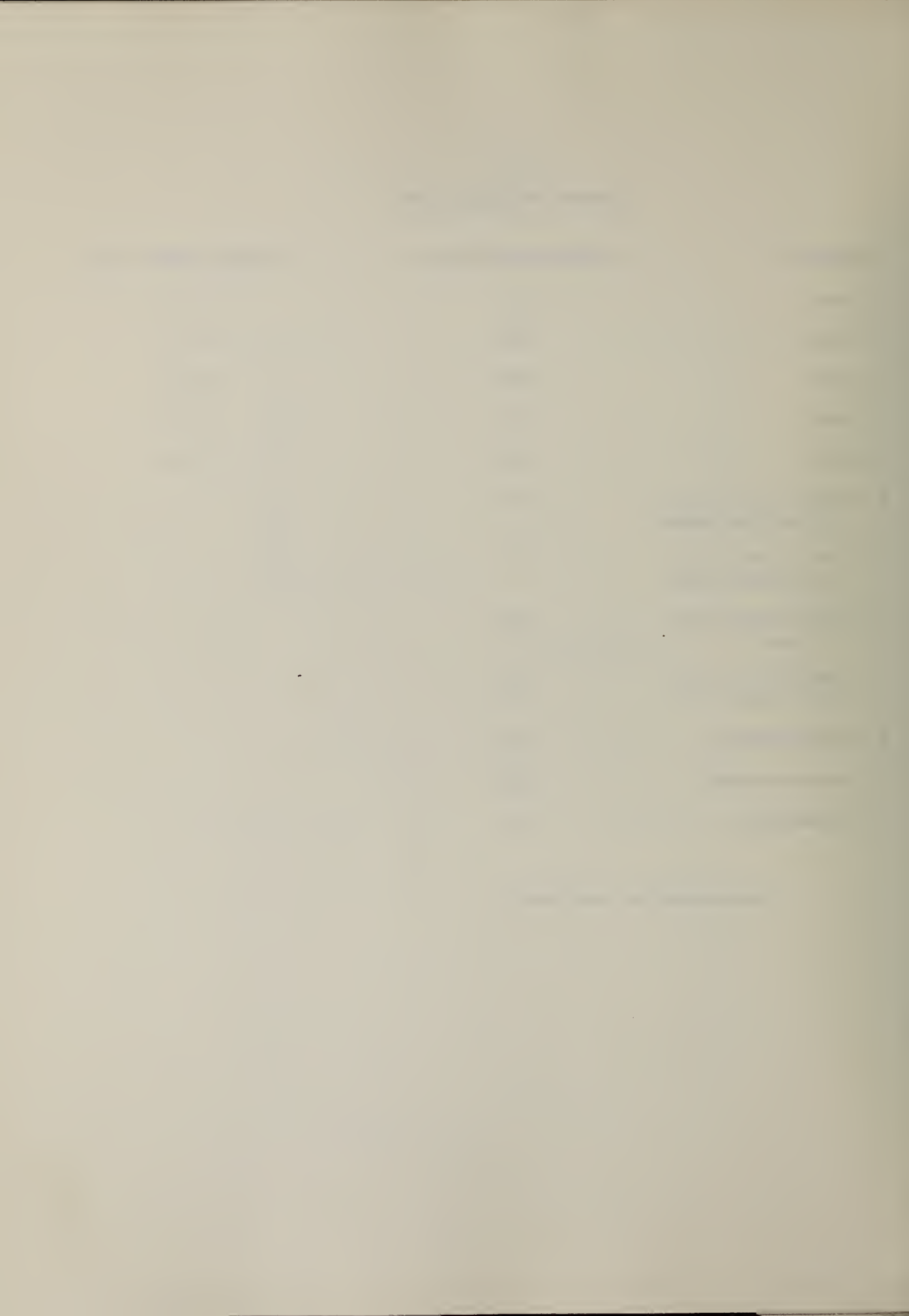
B = 752.8 mm Hg



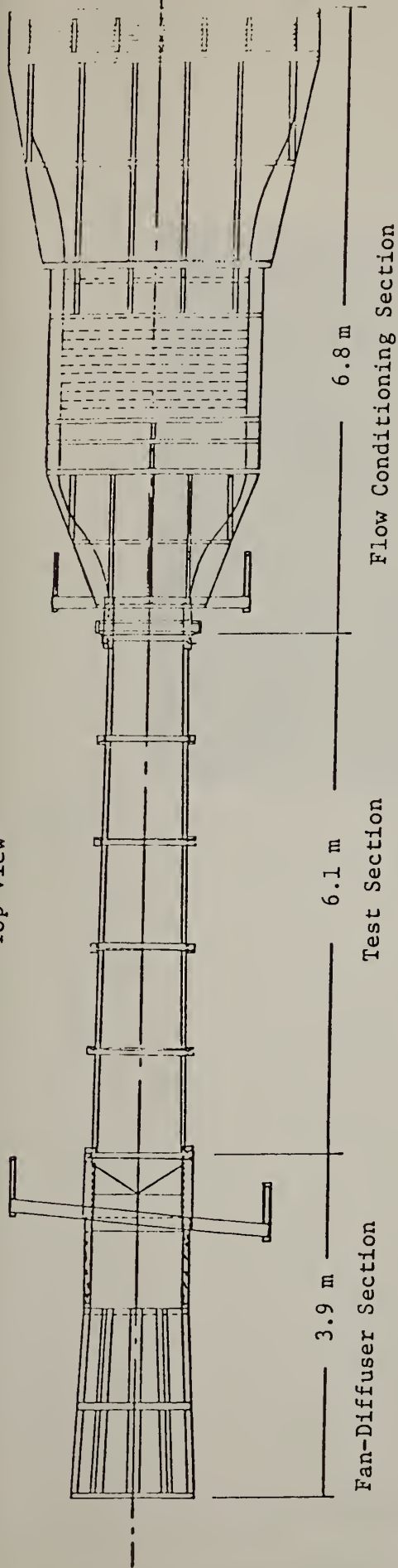
Table K  
Minimum Operating Speeds

| INSTRUMENT                                    | STOPPING SPEED (fpm) | STARTING SPEED (fpm) |
|---|----------------------|----------------------|
| A, vane                                       | 54                   | 63.3                 |
| B, vane                                       | 18.2                 | 23.3                 |
| C, vane                                       | 60.6                 | 66.6                 |
| D, vane                                       | 31.7                 | 47.8                 |
| E, vane                                       | 39.5                 | 59.6                 |
| F,* impact-deflection,<br>low and high ranges | 100                  |                      |
| F,* impact-deflection,<br>low velocity probe  | 40                   |                      |
| G,* impact-deflection,<br>low range           | 53.0                 |                      |
| G,* impact-deflection,<br>high range          | 50.8                 |                      |
| H, vortex-shedding                            | 54.1                 |                      |
| I, vortex-shedding                            | 58.8                 |                      |
| J,* heated-foil                               | 16                   |                      |

\*Determined by resolution



Top View



Entrance  
Cone

Settling  
Chamber

Contraction

Test Section

Fan

Diffuser

Side View

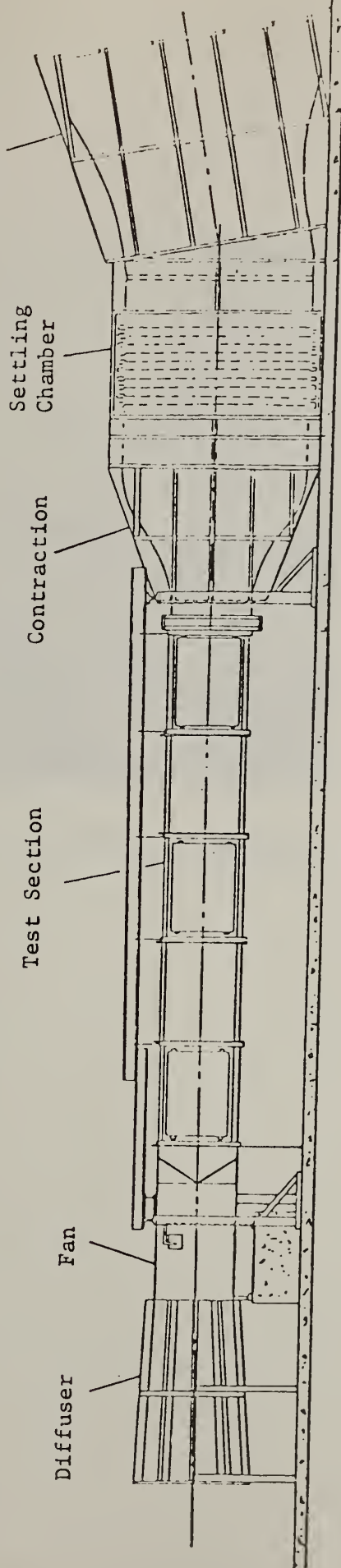


FIGURE 1. SCHEMATIC OF FLOW FACILITY.



FIGURE 2. INSTRUMENT A MOUNTED IN THE TUNNEL, SHOWING METHOD OF SUPPORT.



FIGURE 3. INSTRUMENT B MOUNTED IN THE TUNNEL, SHOWING METHOD OF SUPPORT.



FIGURE 4. INSTRUMENT C MOUNTED IN THE TUNNEL, SHOWING METHOD OF SUPPORT.



FIGURE 5. INSTRUMENT D MOUNTED IN THE TUNNEL, SHOWING METHOD OF SUPPORT.



FIGURE 6. INSTRUMENT E MOUNTED IN THE TUNNEL, SHOWING METHOD OF SUPPORT.



FIGURE 7. INSTRUMENT F, WITH PITOT PROBE MOUNTED IN TUNNEL  
SHOWING METHOD OF SUPPORT.



FIGURE 8. INSTRUMENT F WITH DIFFUSER PROBE MOUNTED IN TUNNEL  
SHOWING METHOD OF SUPPORT.



FIGURE 9. INSTRUMENT F WITH LOW-VELOCITY PROBE MOUNTED IN TUNNEL  
SHOWING METHOD OF SUPPORT.



FIGURE 10. INSTRUMENT G MOUNTED IN THE TUNNEL, SHOWING METHOD OF SUPPORT (VIEWED LOOKING DOWNSTREAM).



FIGURE 11. INSTRUMENTS H AND I MOUNTED IN TUNNEL, SHOWING METHOD OF SUPPORT (VIEWED LOOKING DOWNSTREAM).



FIGURE 12. INSTRUMENT J MOUNTED IN TUNNEL, SHOWING METHOD OF SUPPORT.

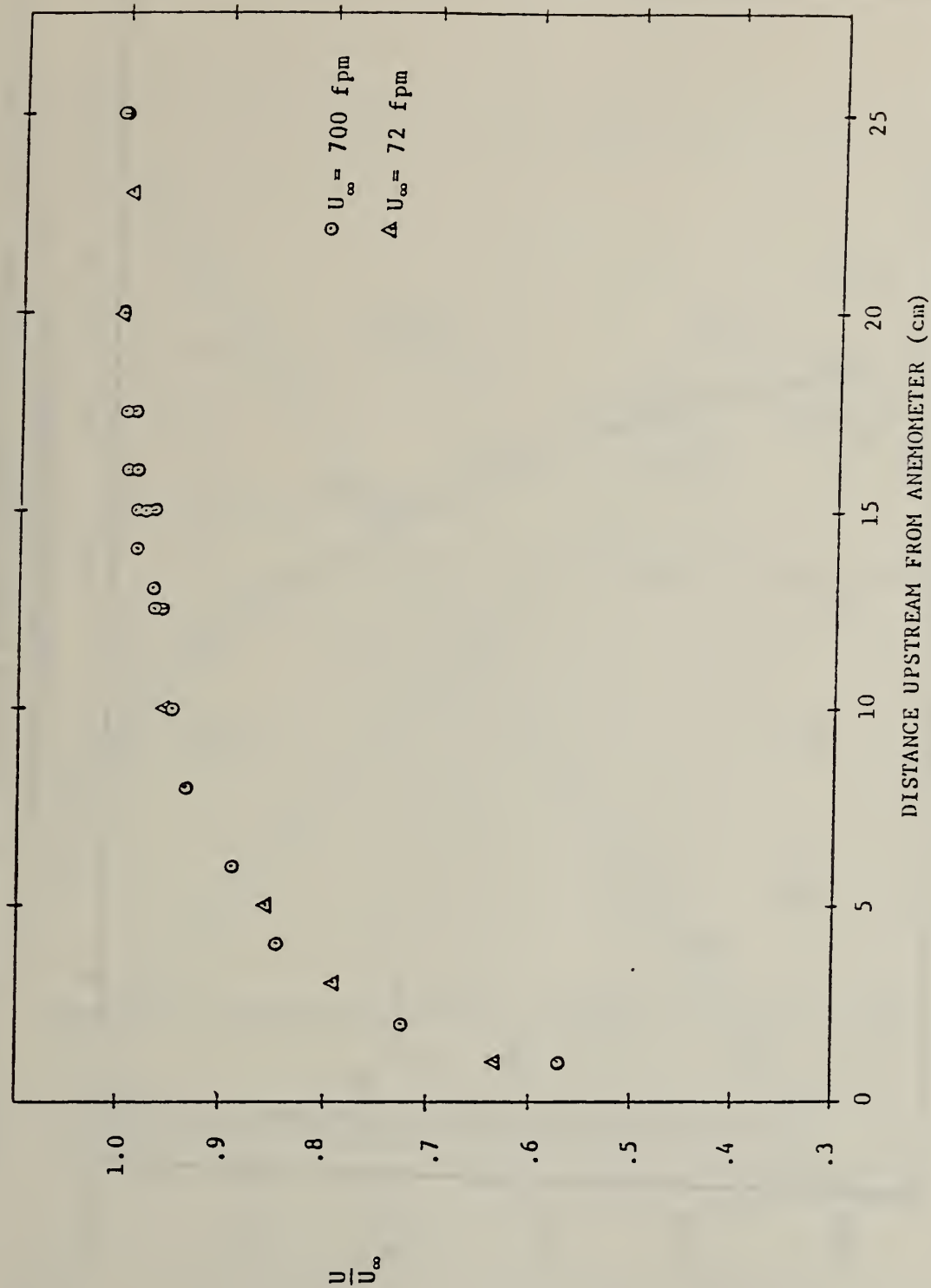


FIGURE 13. VARIATION IN VELOCITY WITH DISTANCE UPSTREAM FROM INSTRUMENT A.

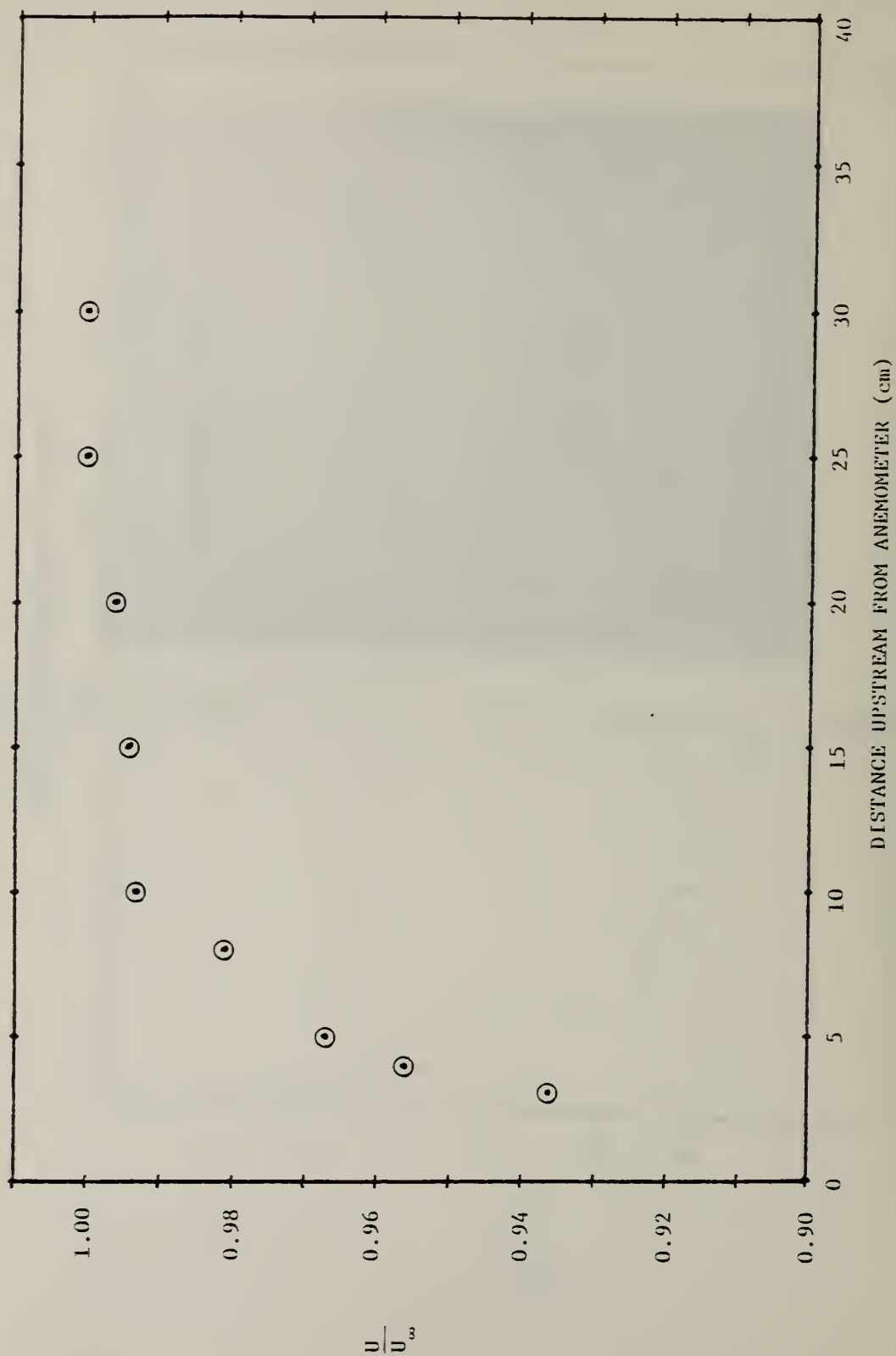


FIGURE 14. VARIATION IN VELOCITY WITH DISTANCE UPSTREAM OF INSTRUMENT F WITH LOW VELOCITY PROBE.  $U_\infty = 70$  fpm.

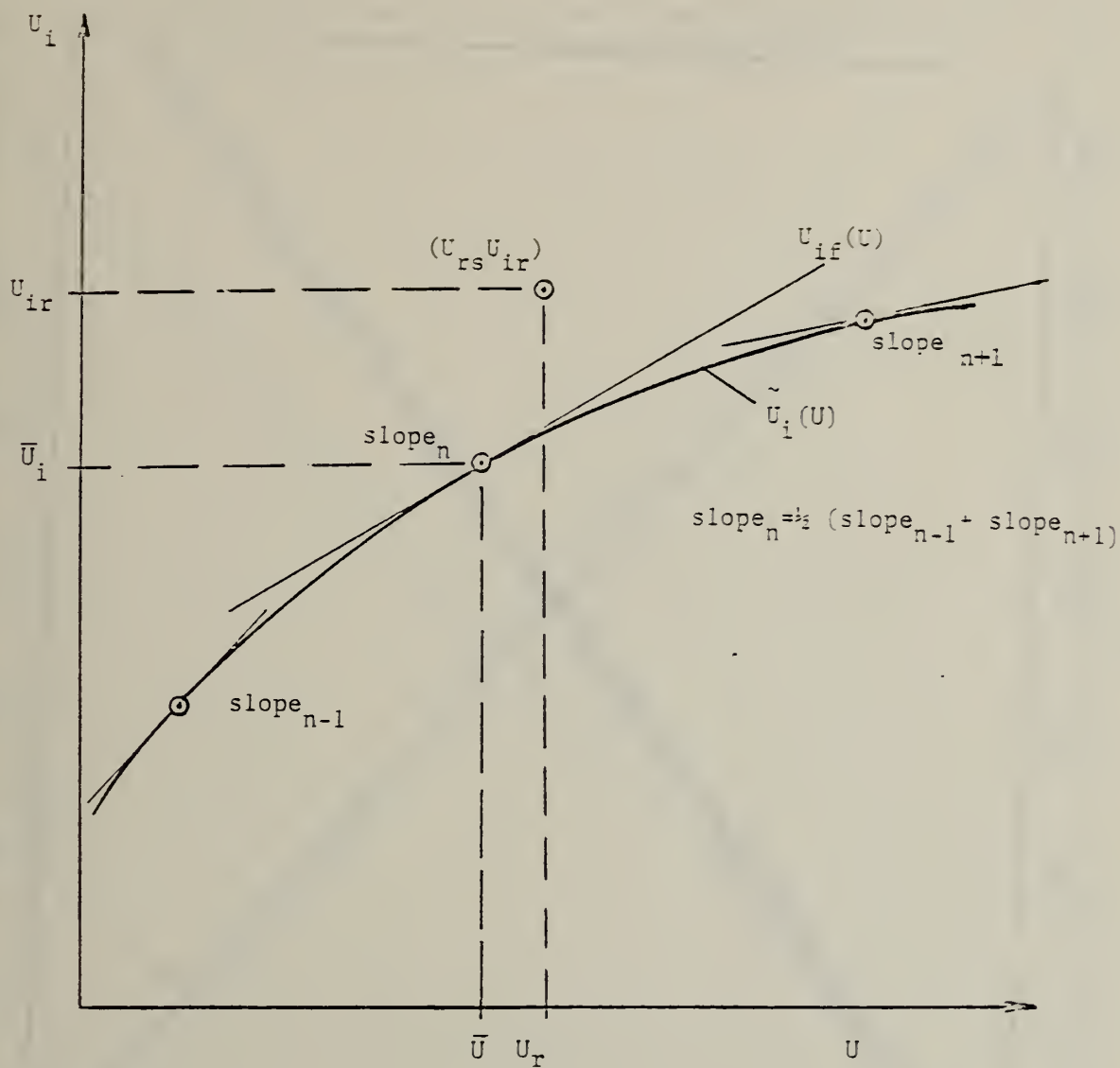


FIGURE 15. DEFINITION OF TERMS FOR CALCULATION OF  $\sigma_i$ .

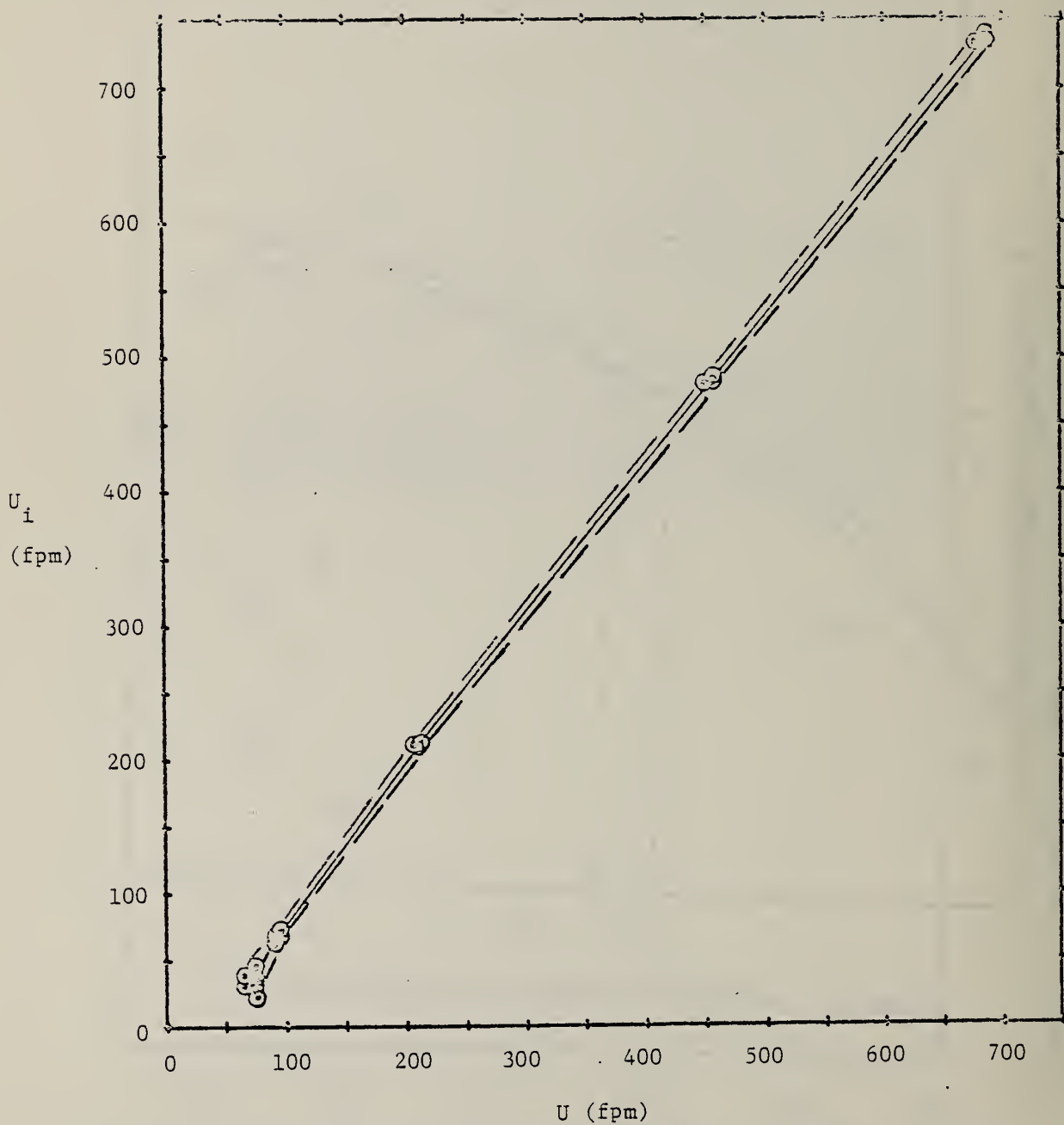


FIGURE 16. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2\sigma$  CURVES. INSTRUMENT A.

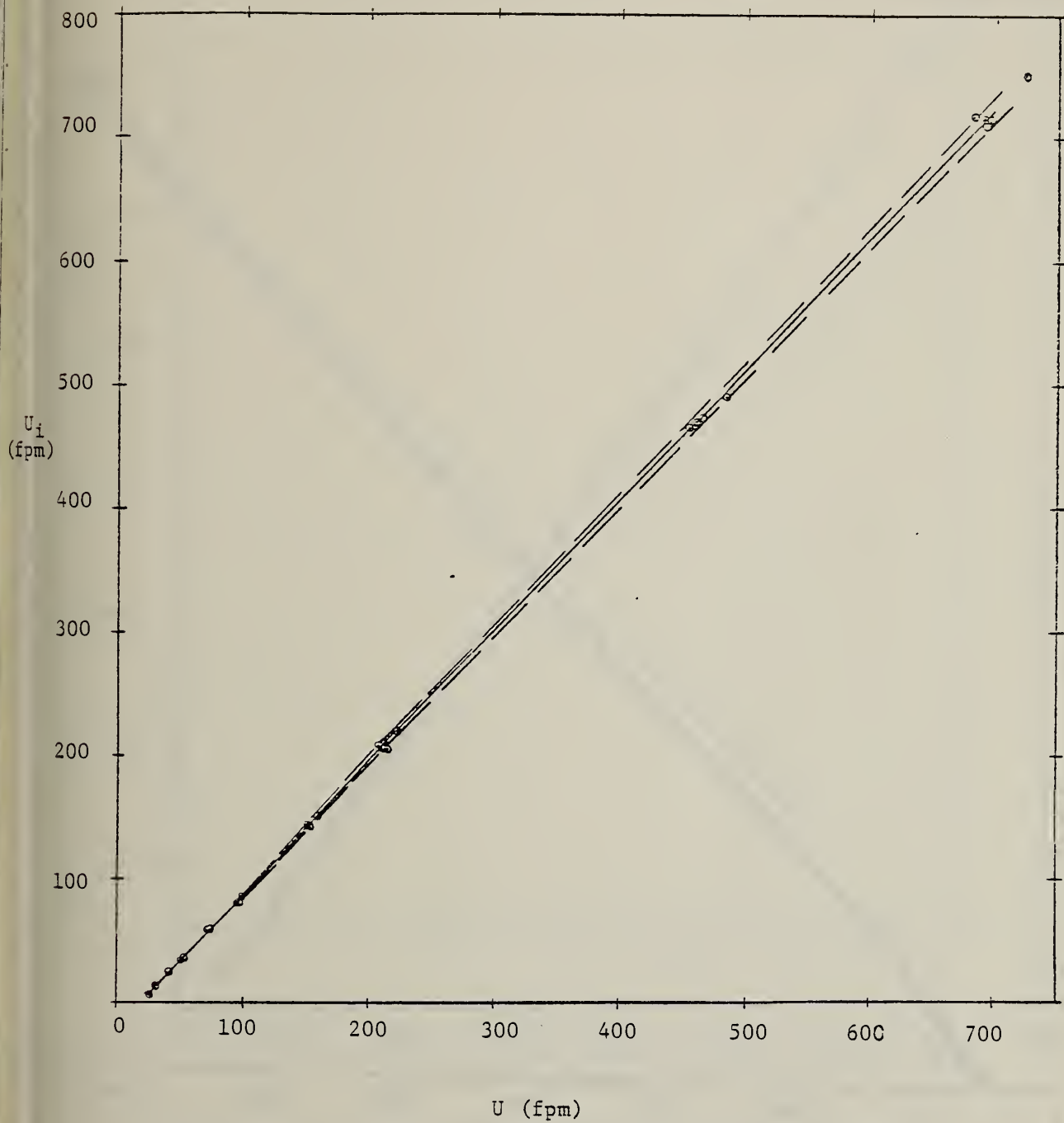


FIGURE 17. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2\sigma$  CURVES.  
INSTRUMENT B.

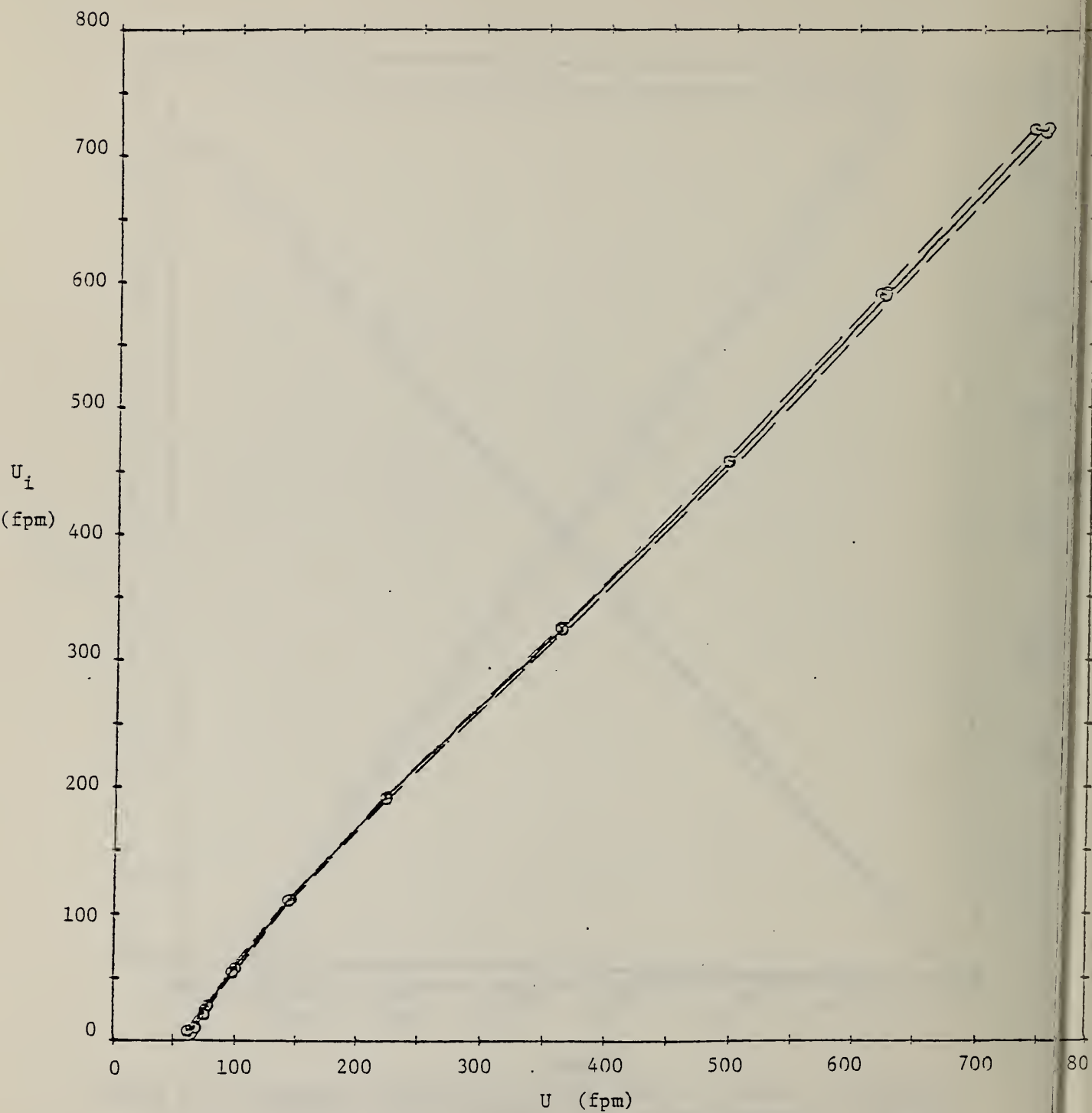


FIGURE 18. INDICATED VERSUS TRUE VELOCITY WITH  $\pm$  CURVES. INSTRUMENT C.

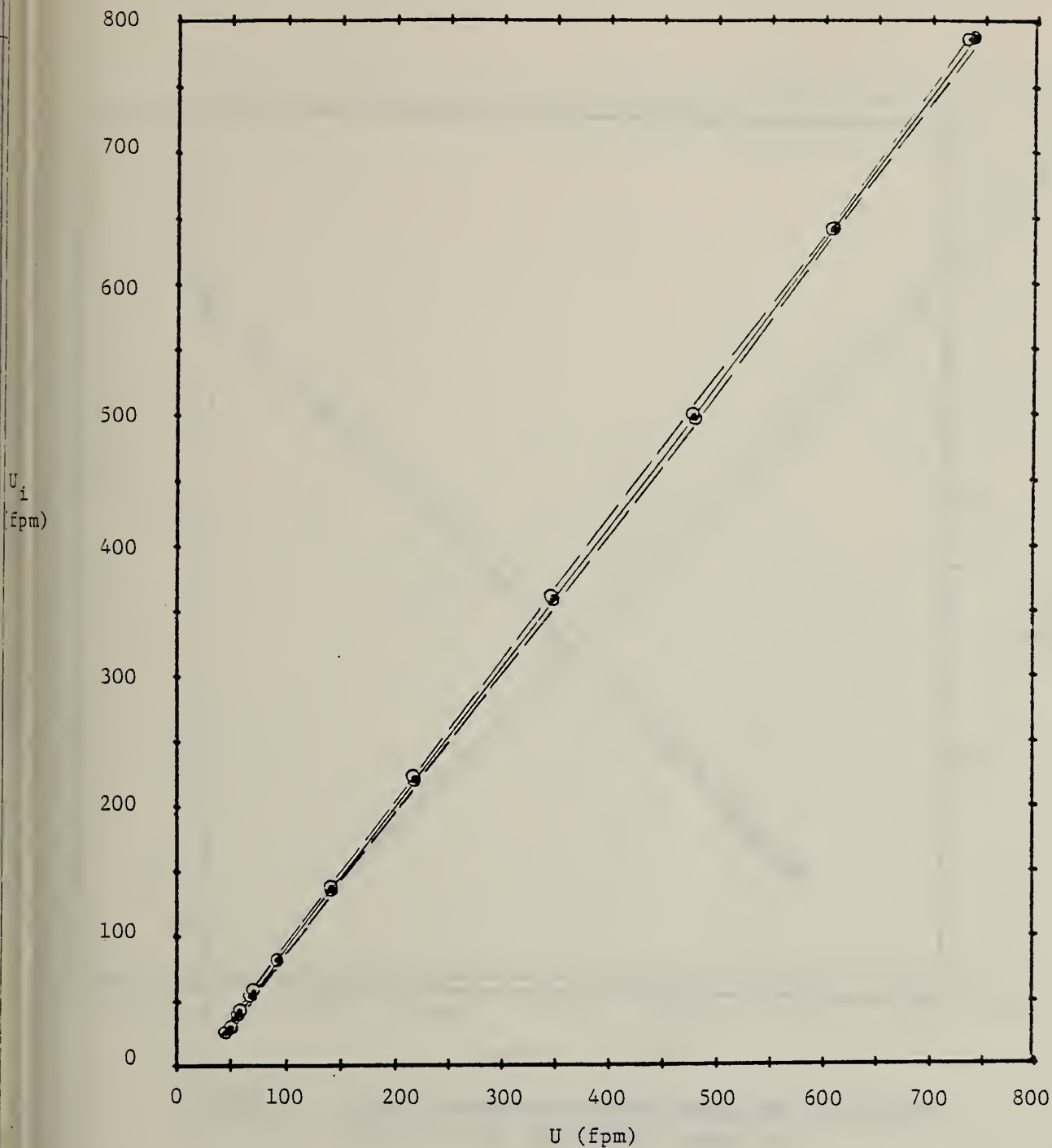


FIGURE 19. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2\sigma$  CURVES.  
INSTRUMENT D.

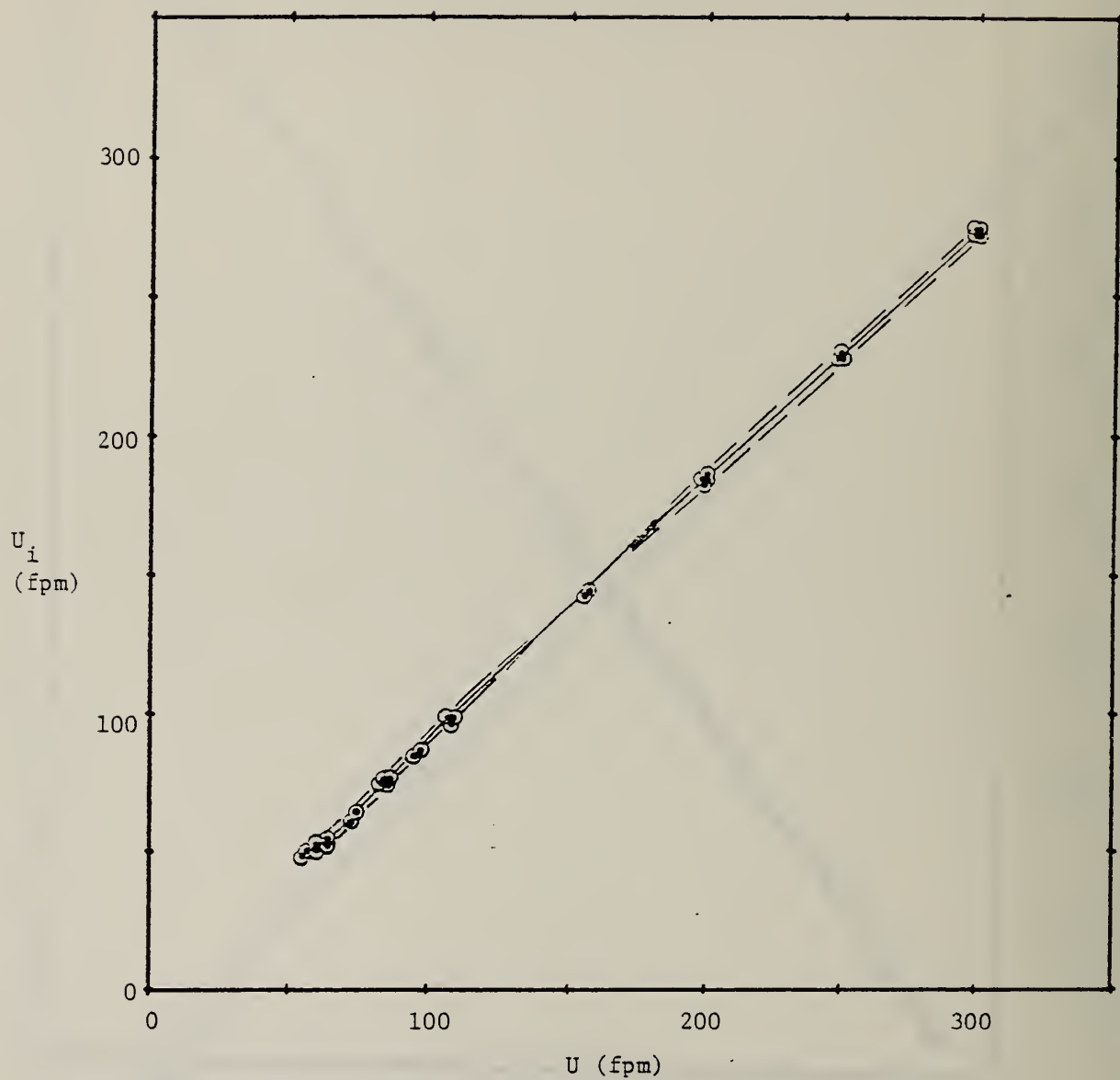


FIGURE 20. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2\sigma$  CURVES, LOW RANGE. INSTRUMENT E.

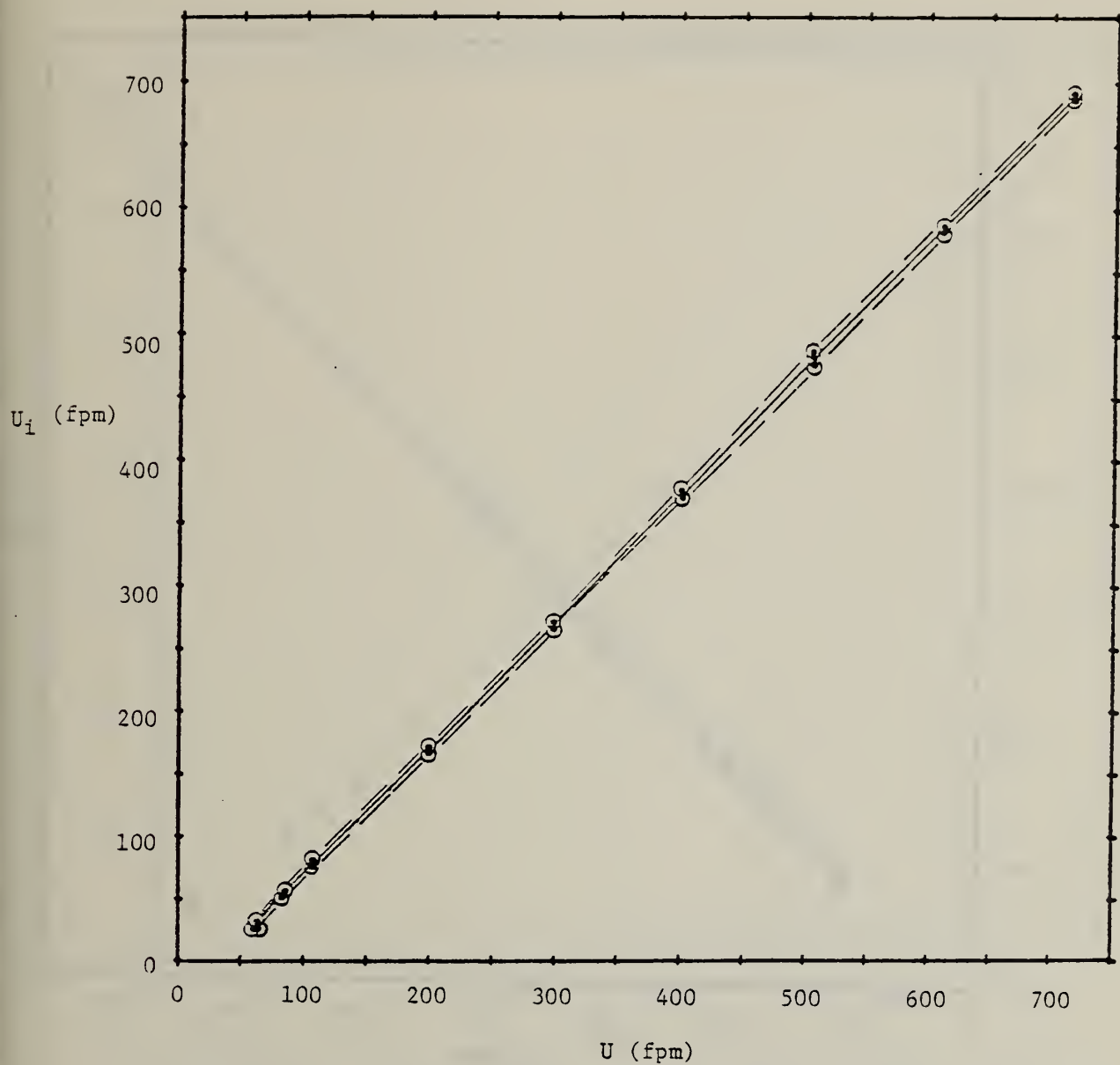


FIGURE 21. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2\sigma$  CURVES, MEDIUM RANGE. INSTRUMENT E.

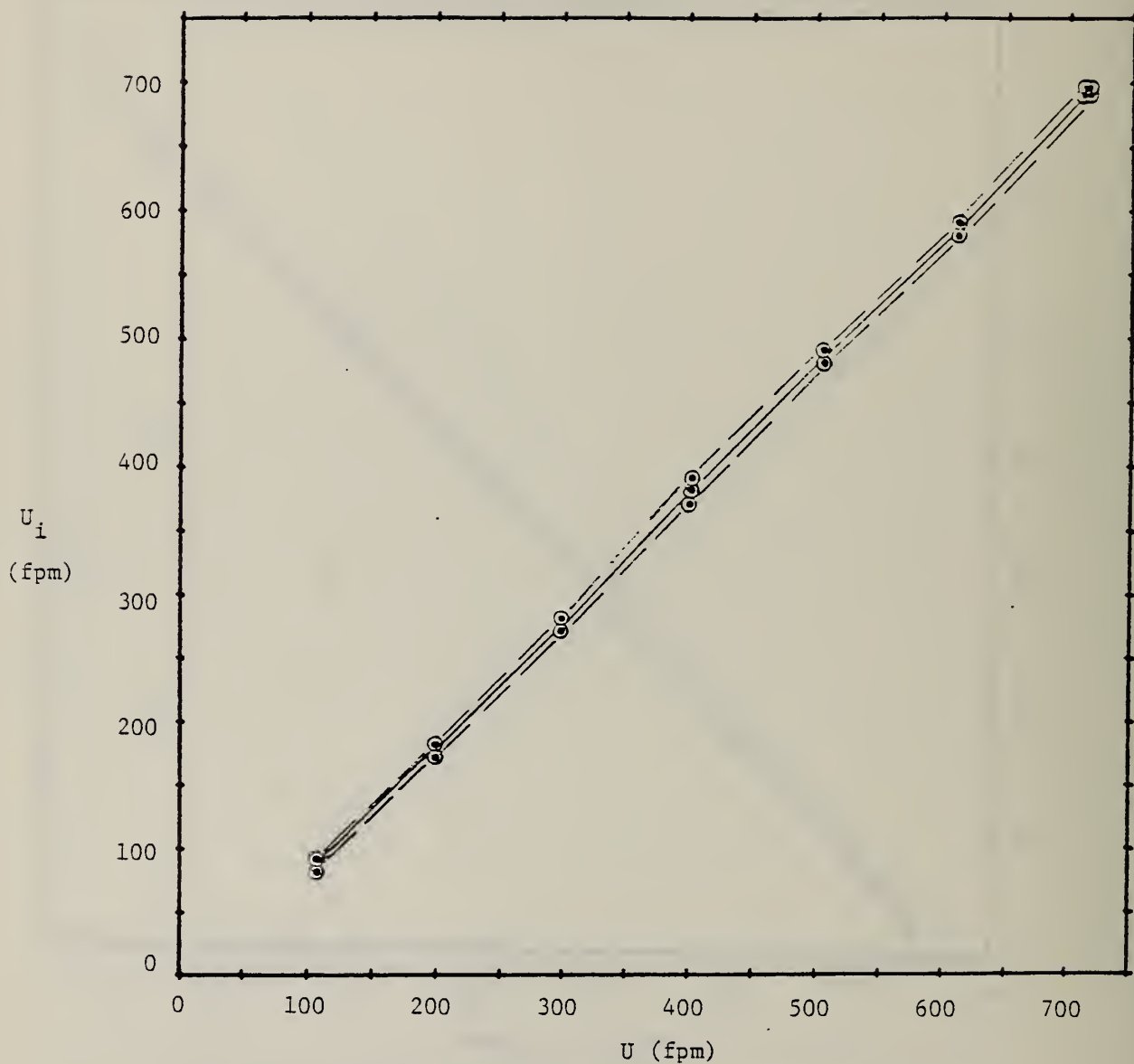


FIGURE 22. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2\sigma$  CURVES, HIGH RANGE. INSTRUMENT E.

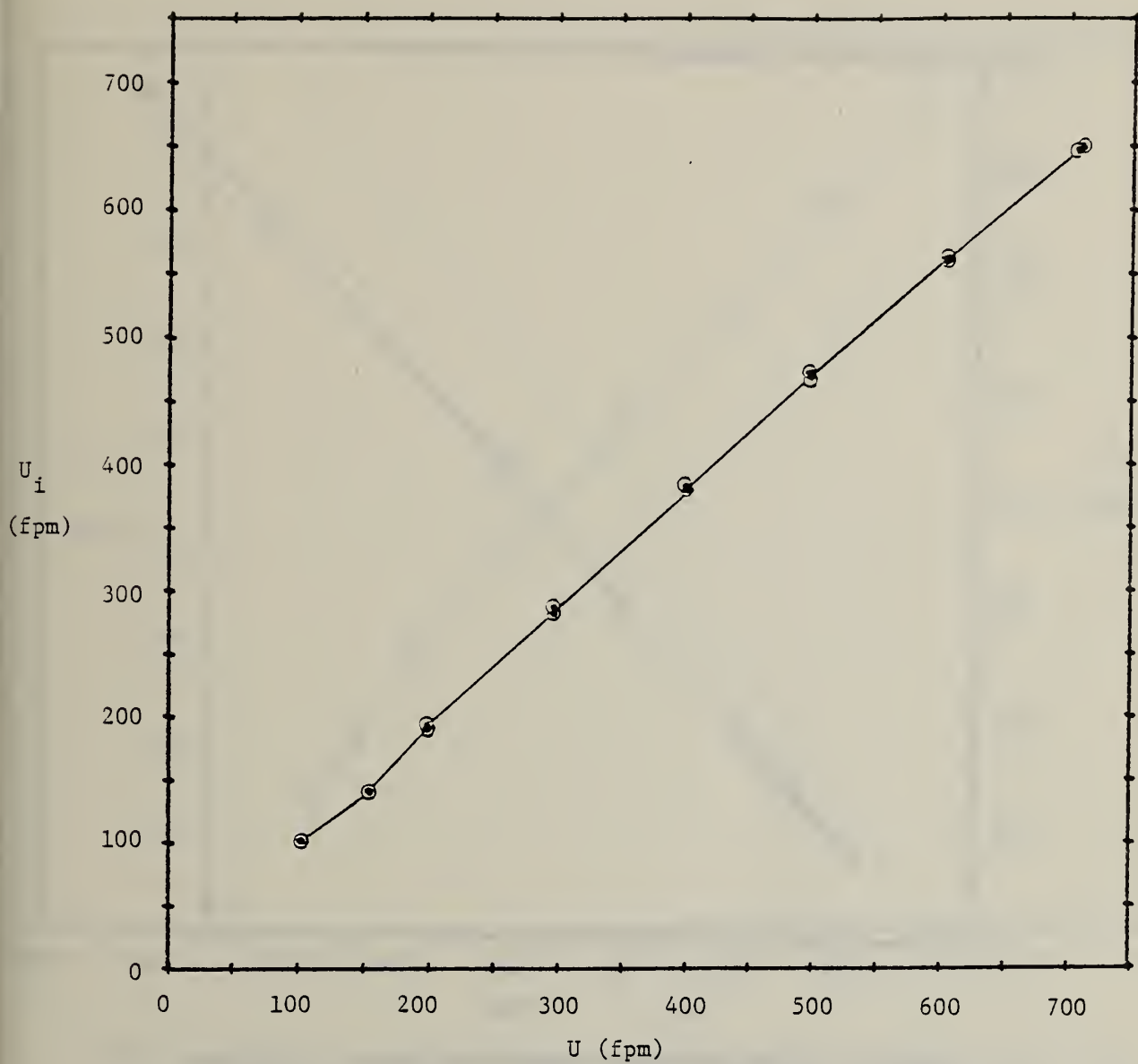


FIGURE 23. INDICATED VERSUS TRUE VELOCITY FOR PITOT PROBE, LOW RANGE. INSTRUMENT F.

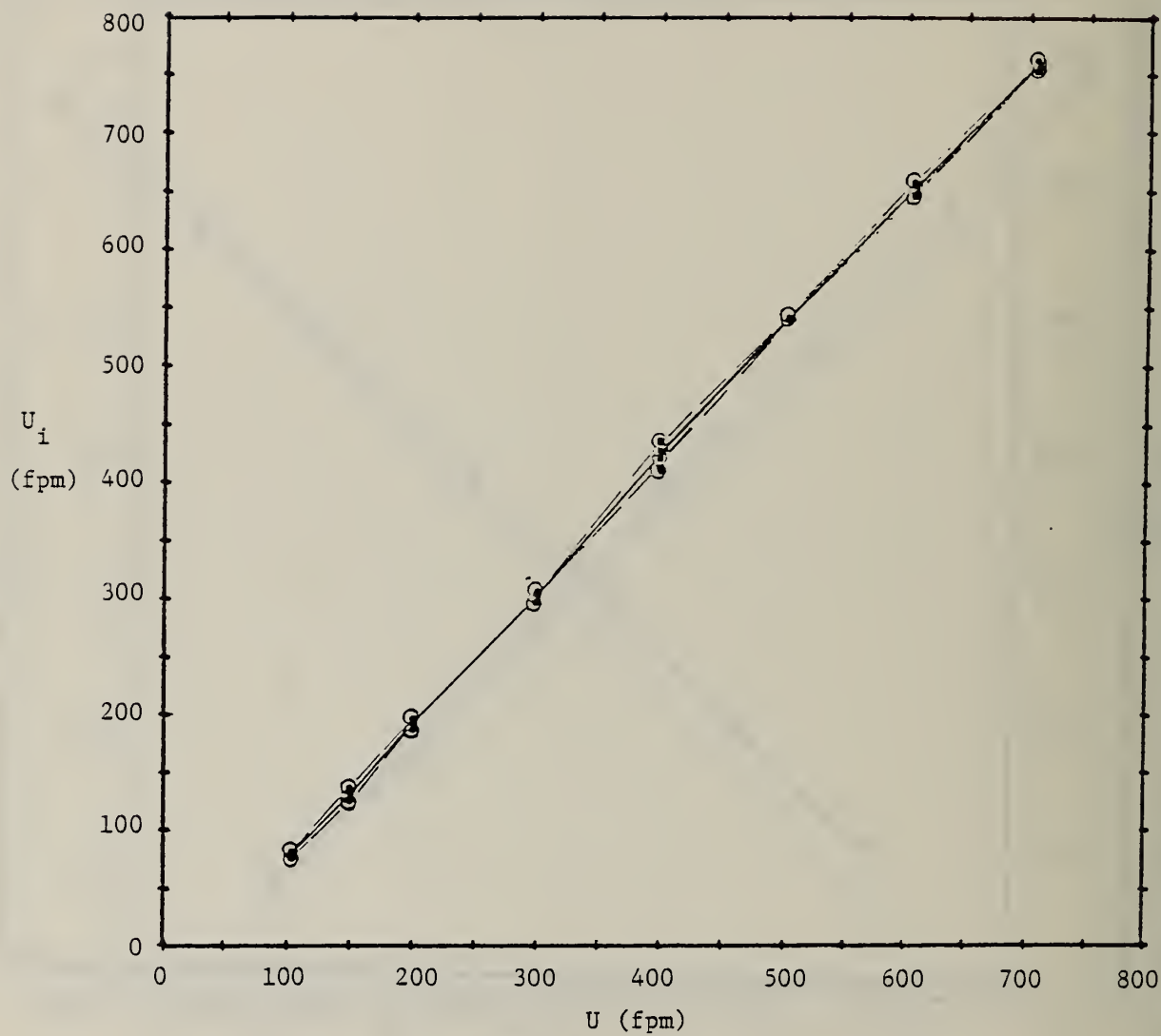


FIGURE 24. INDICATED VERSUS TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE. INSTRUMENT F.

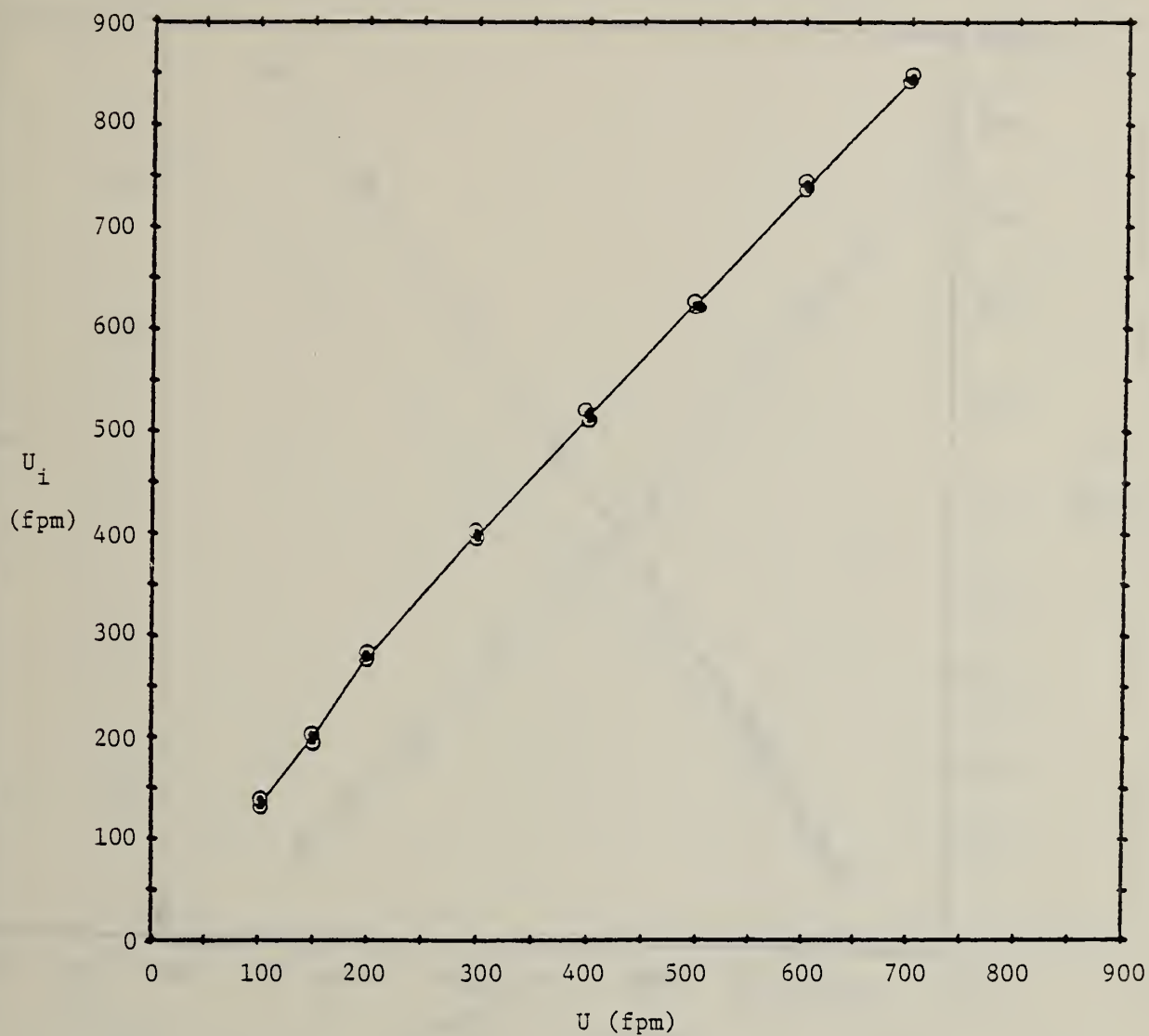


FIGURE 25. INDICATED VERSUS TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE. INSTRUMENT F.

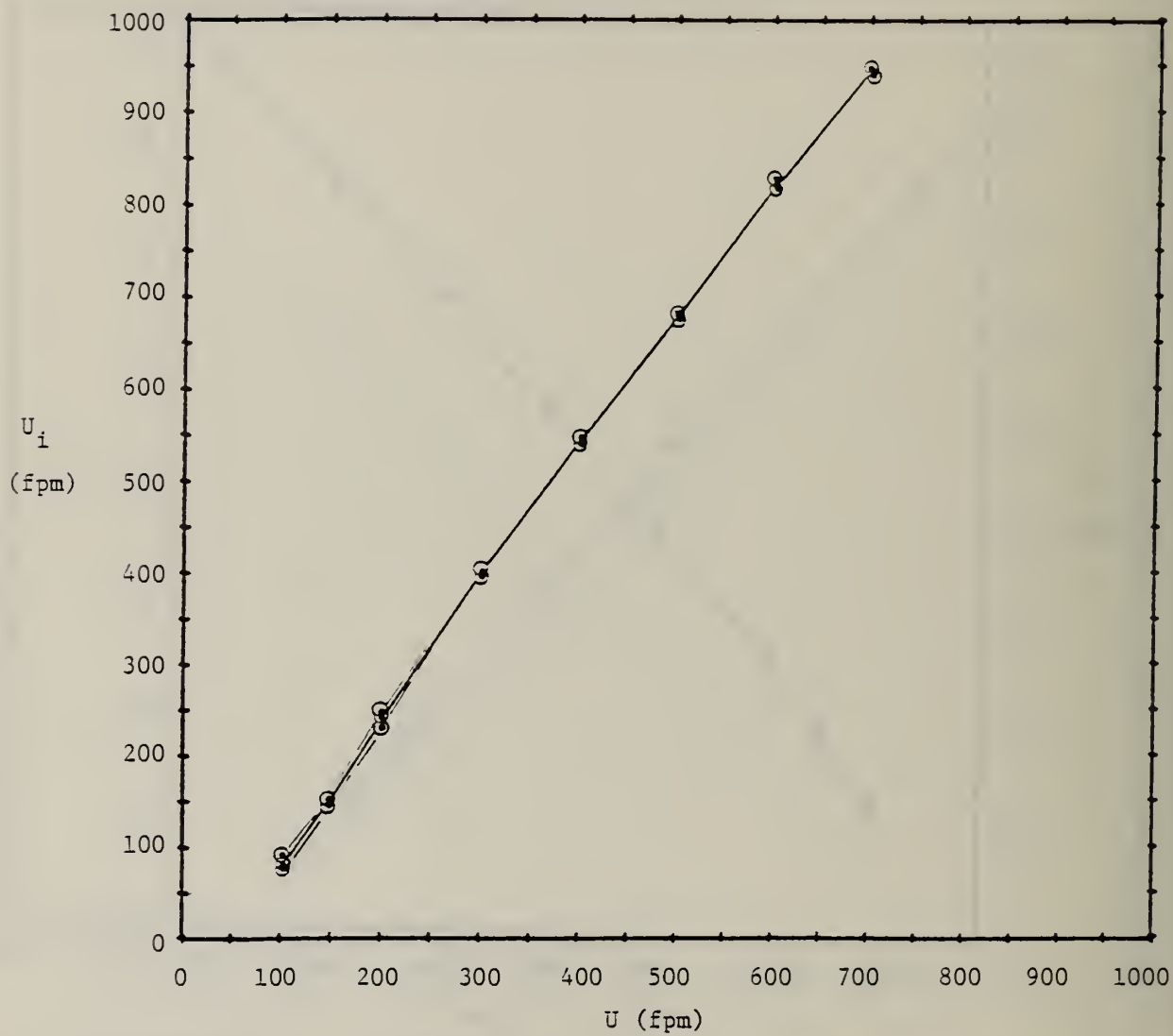


FIGURE 26. INDICATED VERSUS TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE. INSTRUMENT F.

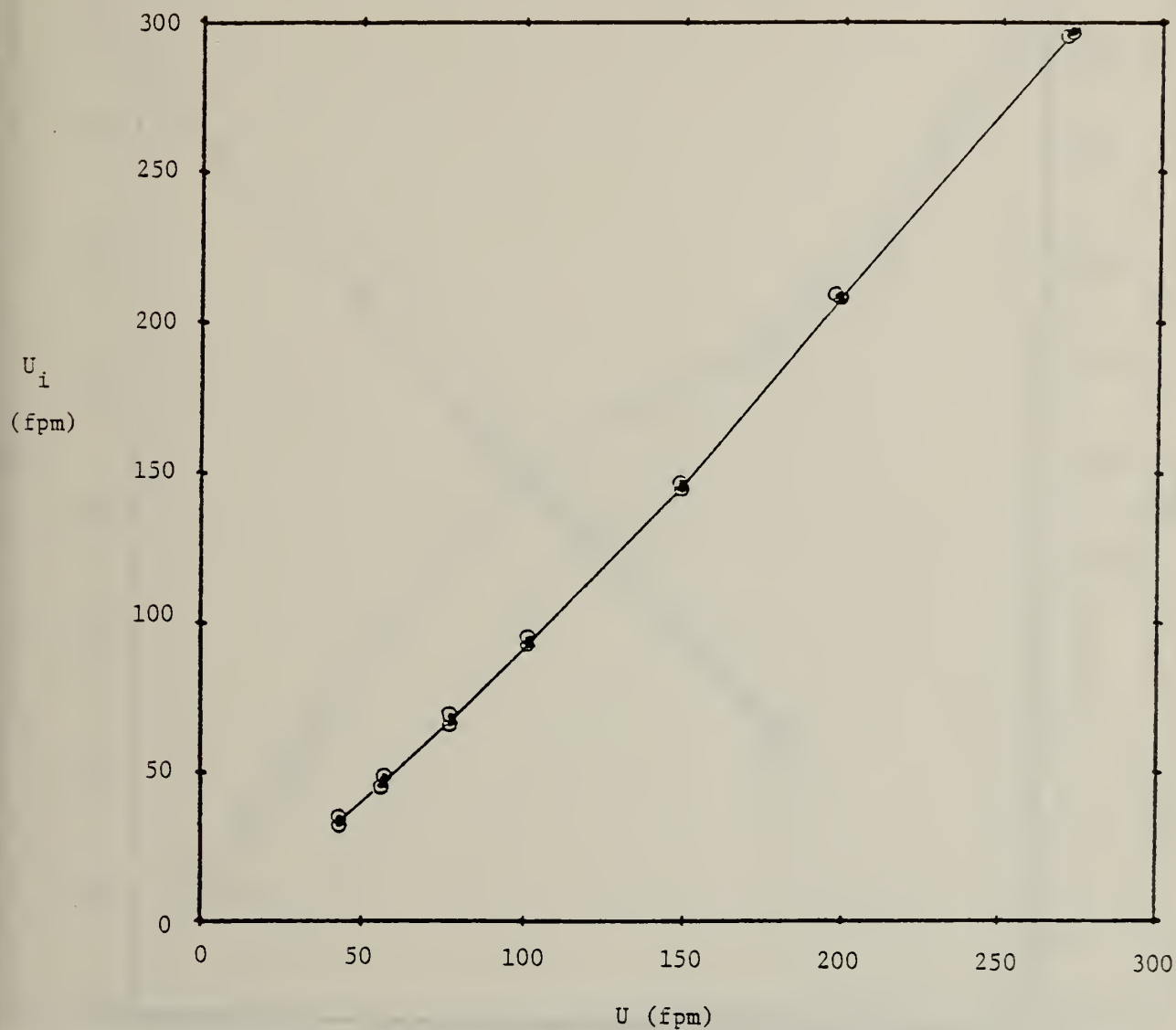


FIGURE 27. INDICATED VERSUS TRUE VELOCITY FOR LOW VELOCITY PROBE.  
INSTRUMENT F.

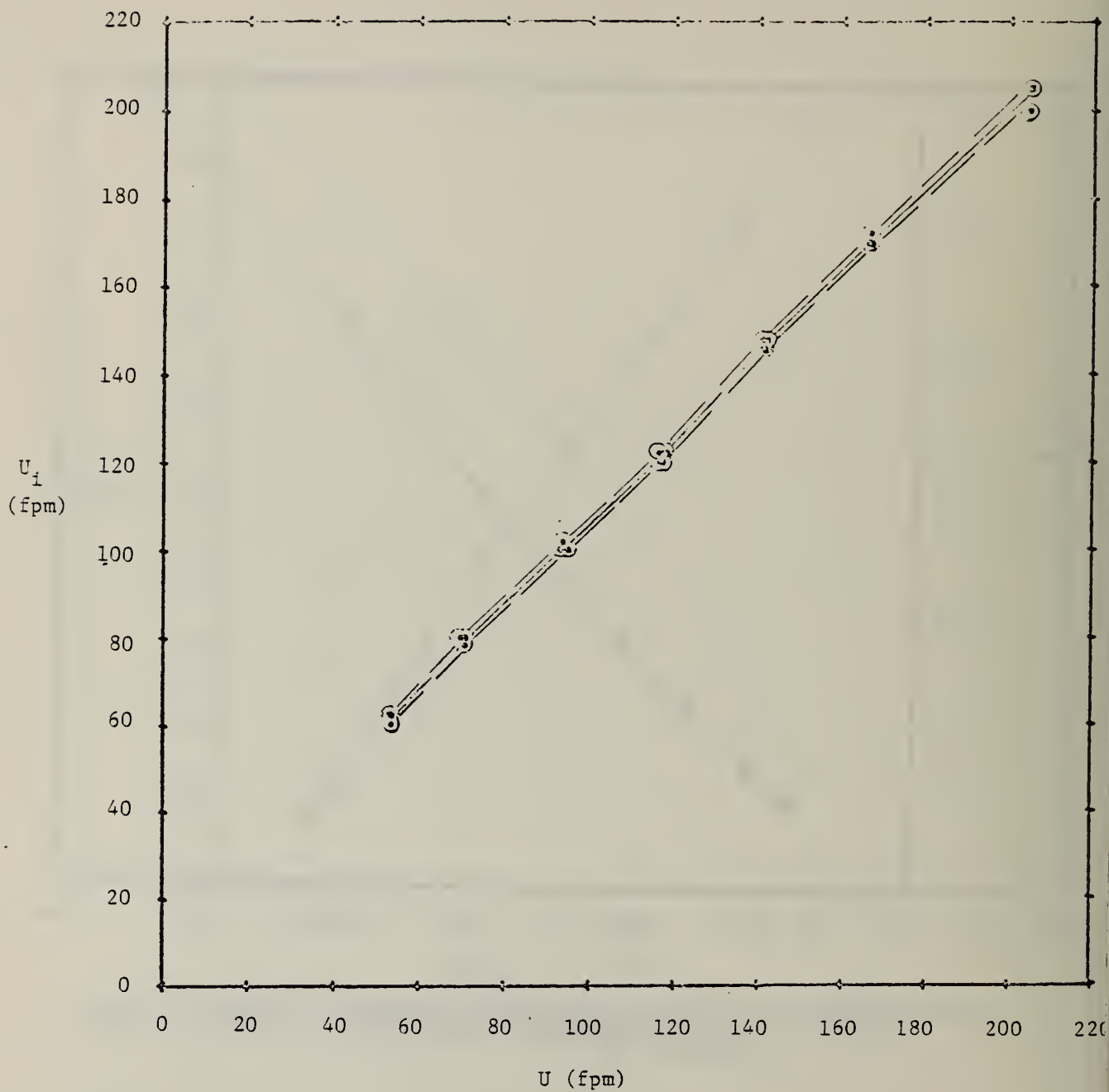


FIGURE 28. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2 \sigma$  CURVES, LOW RANGE.  
INSTRUMENT G.

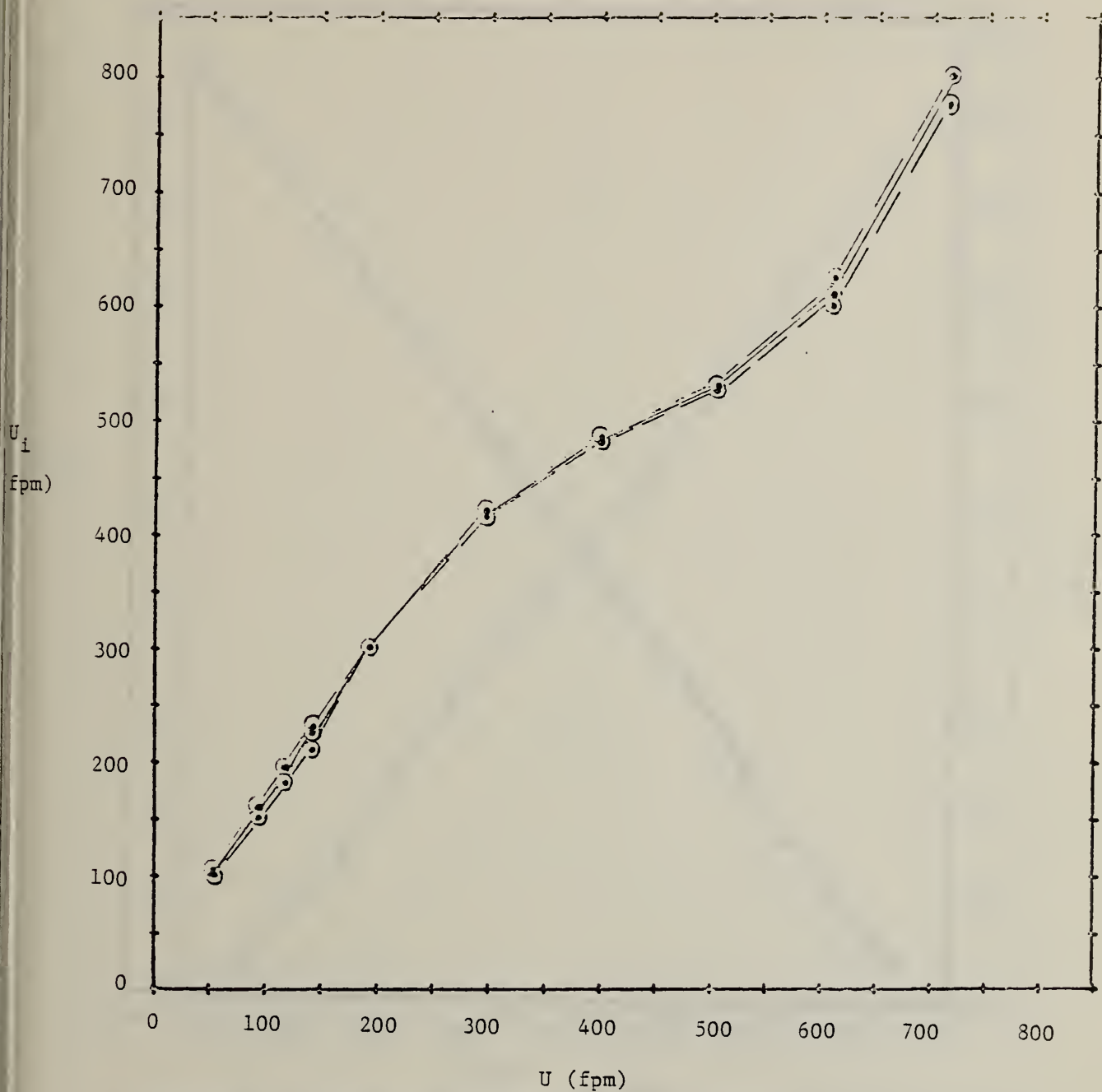


FIGURE 29. INDICATED VERSUS TRUE VELOCITY WITH  $\pm 2 \sigma$  CURVES, HIGH RANGE.  
INSTRUMENT G.

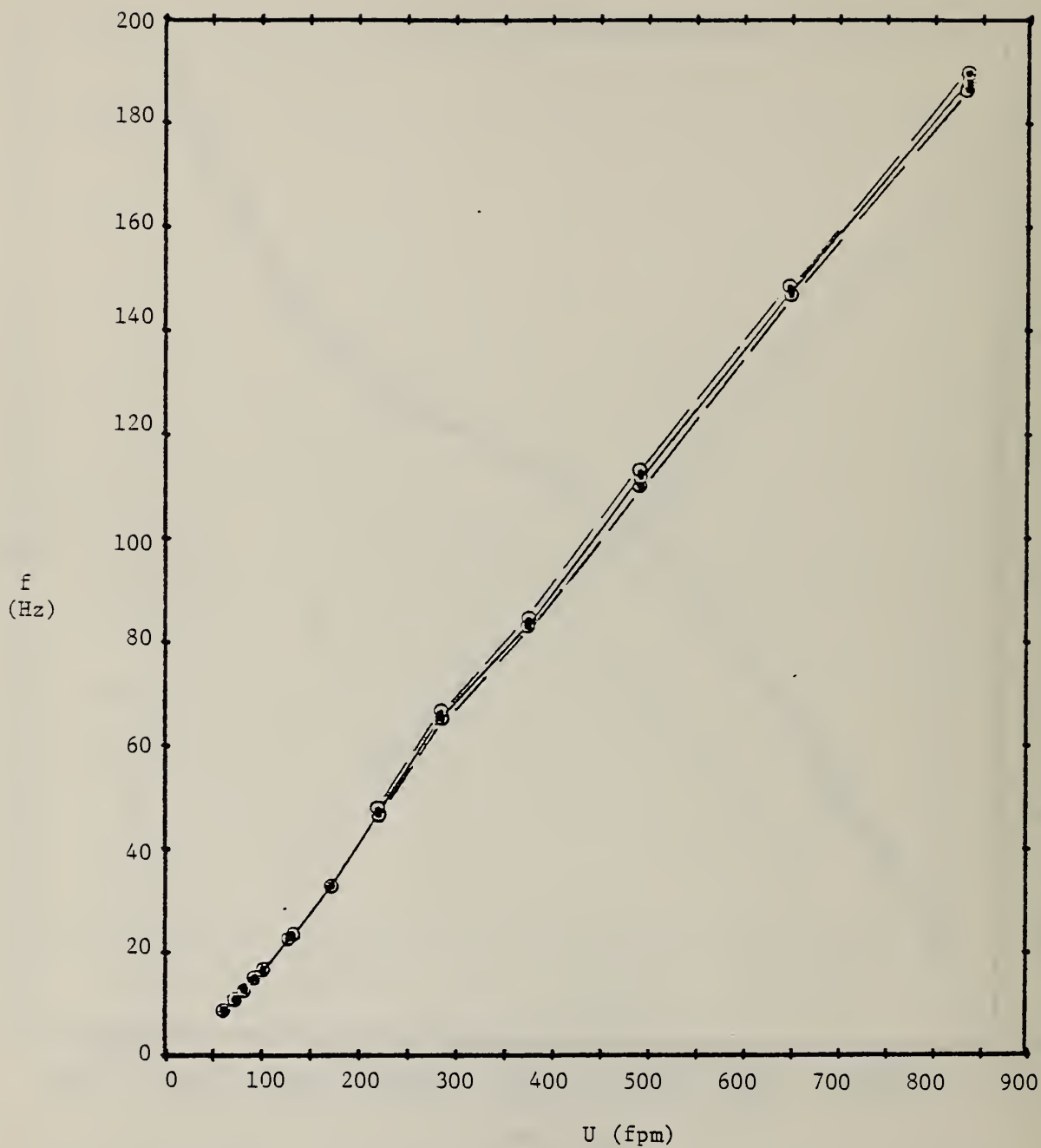


FIGURE 30. PULSE FREQUENCY VERSUS TRUE VELOCITY WITH  $\pm 2\sigma_f$  CURVES.  
INSTRUMENT H.

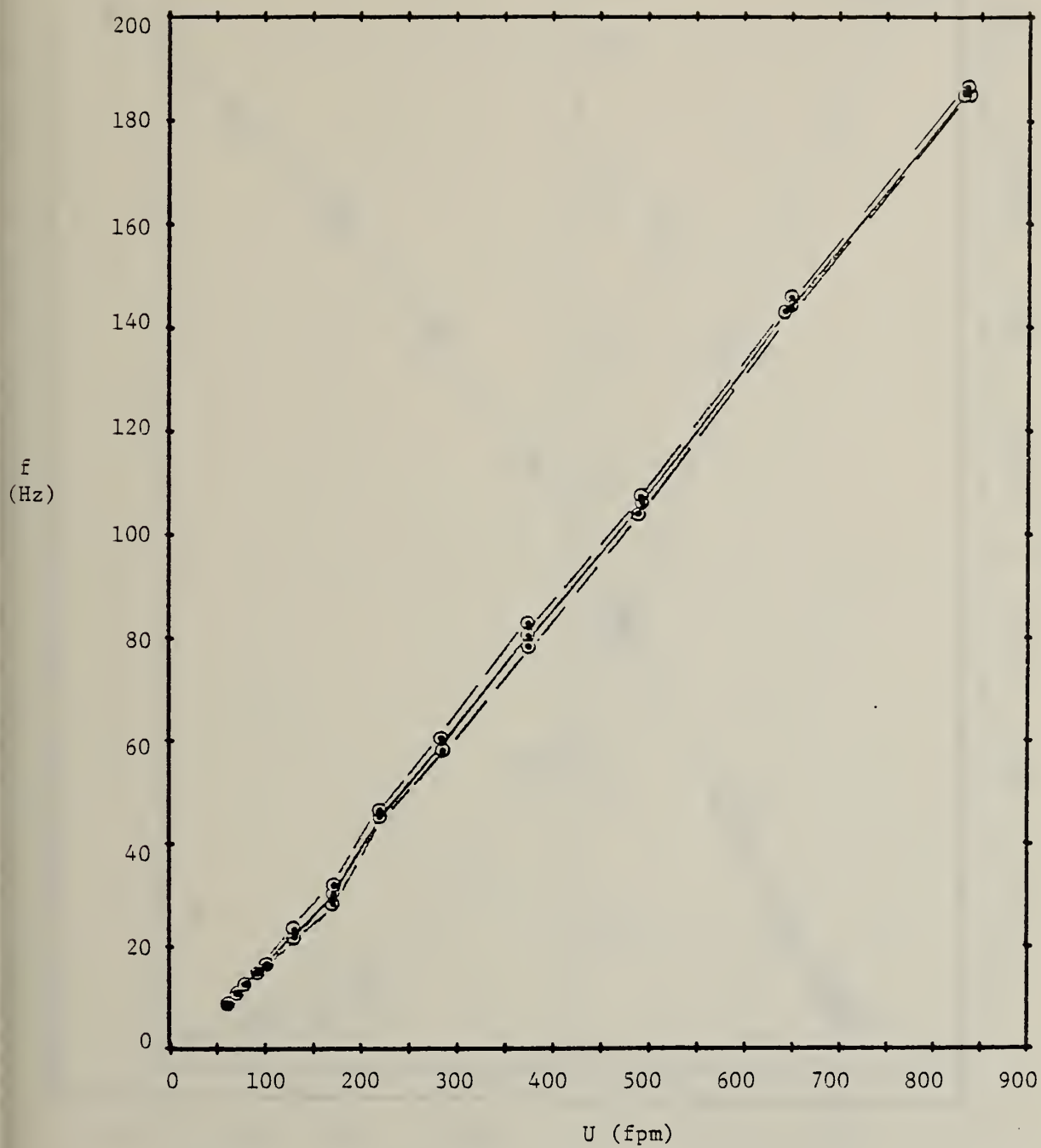


FIGURE 31. PULSE FREQUENCY VERSUS TRUE VELOCITY WITH  $\pm 2\sigma_f$  CURVES.  
INSTRUMENT I.

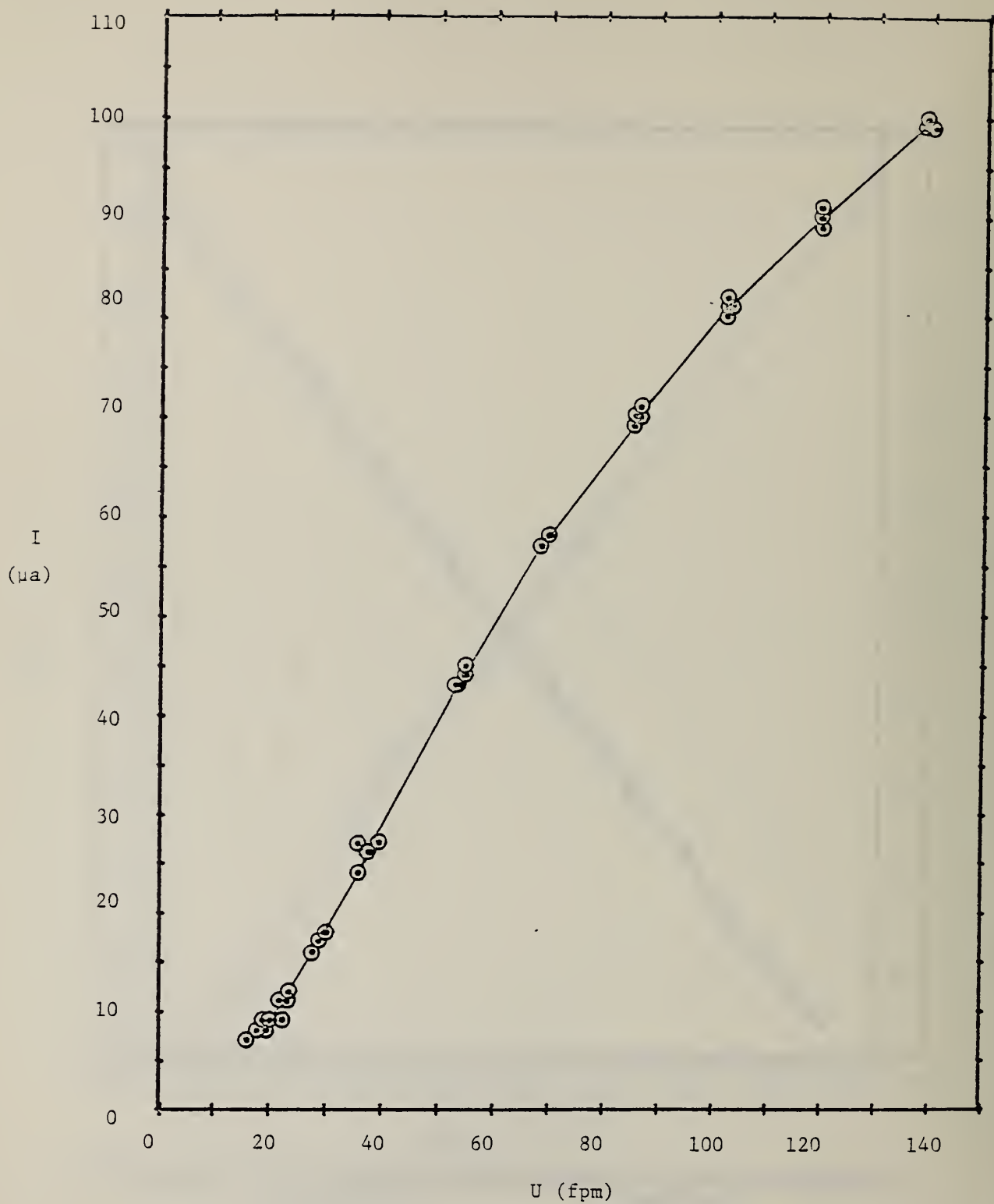


FIGURE 32. OUTPUT OF INSTRUMENT J AGAINST VELOCITY.

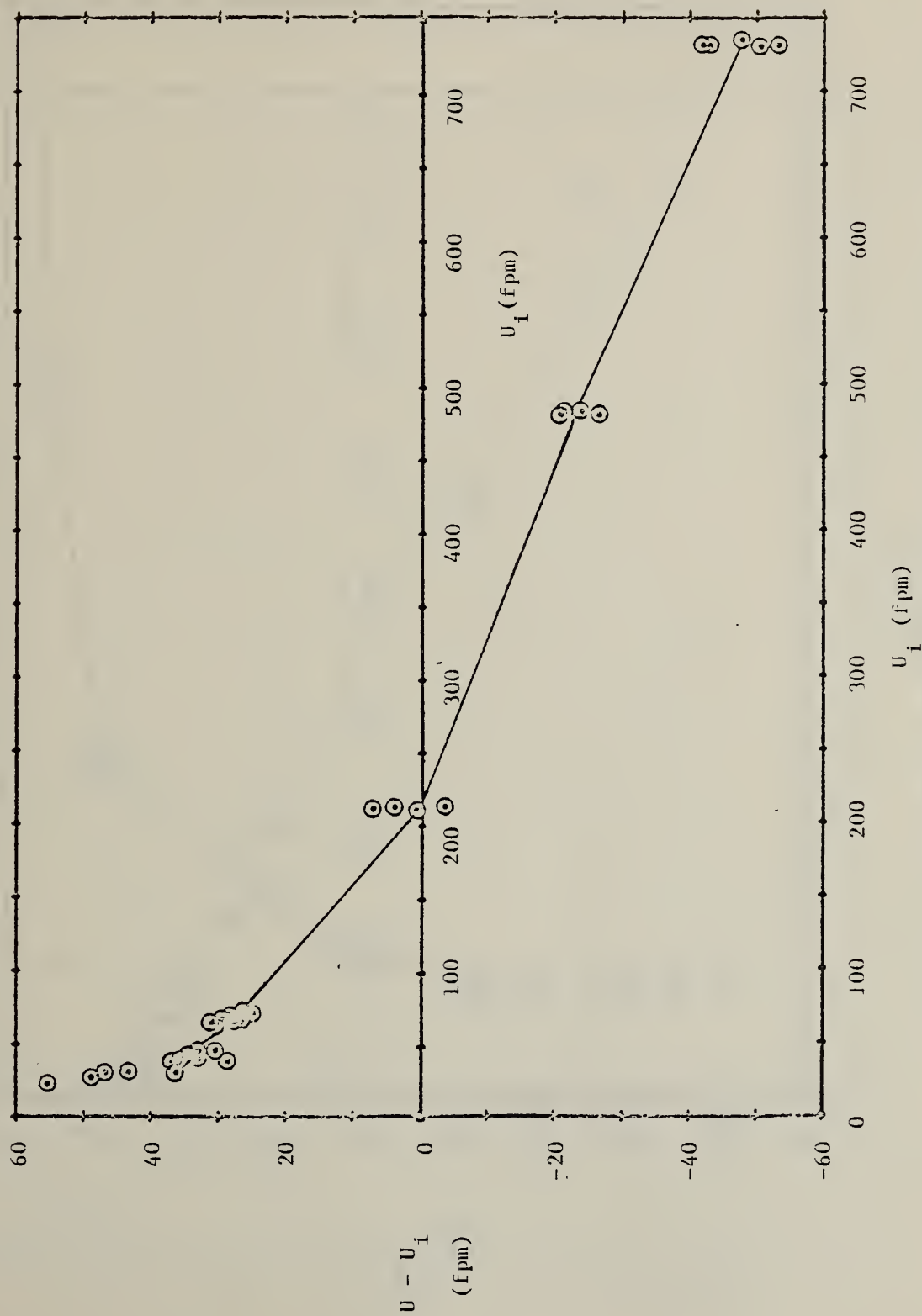


FIGURE 33. DEVIATION OF INDICATED FROM TRUE VELOCITY. INSTRUMENT A.

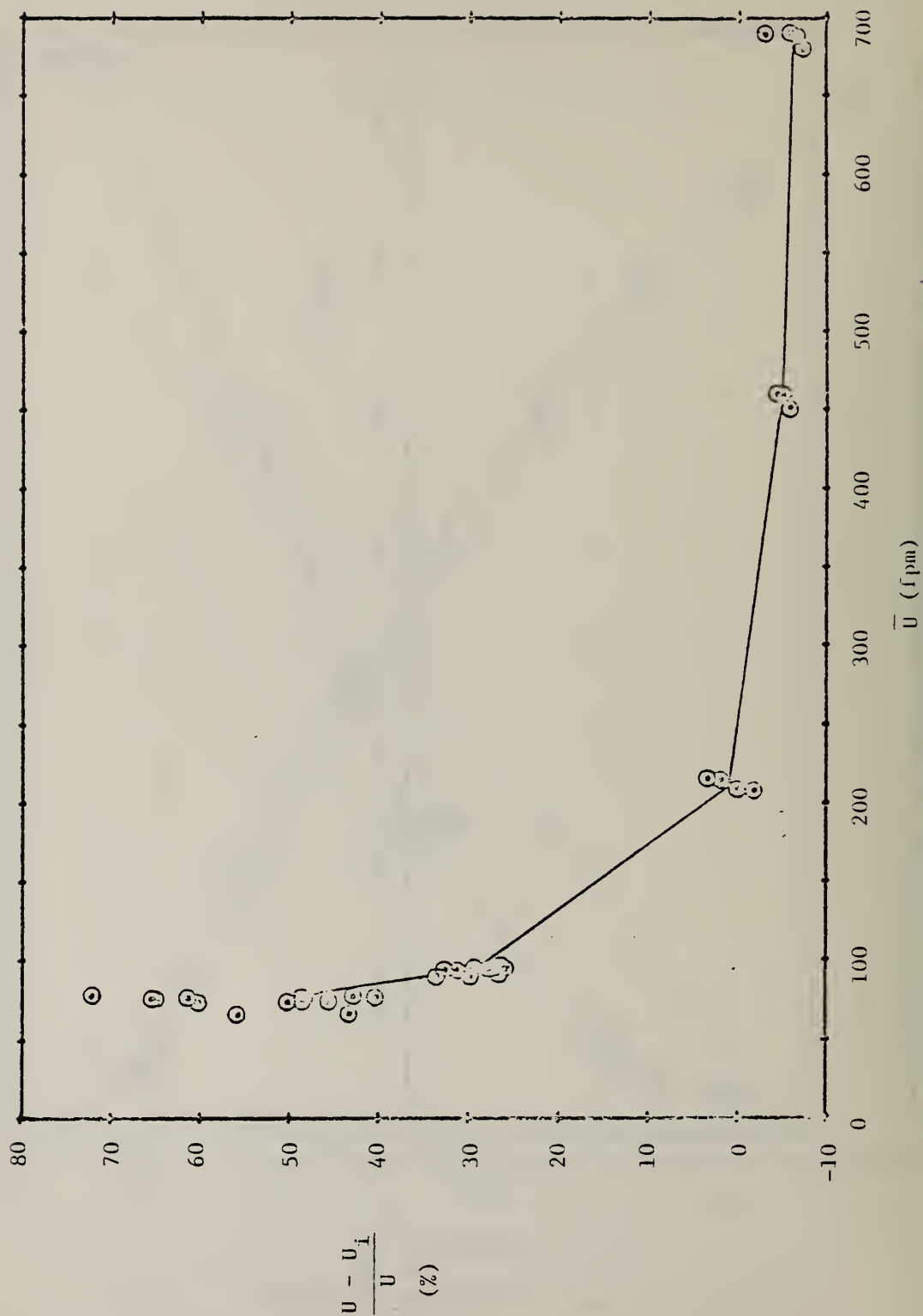


FIGURE 34. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY. INSTRUMENT A.

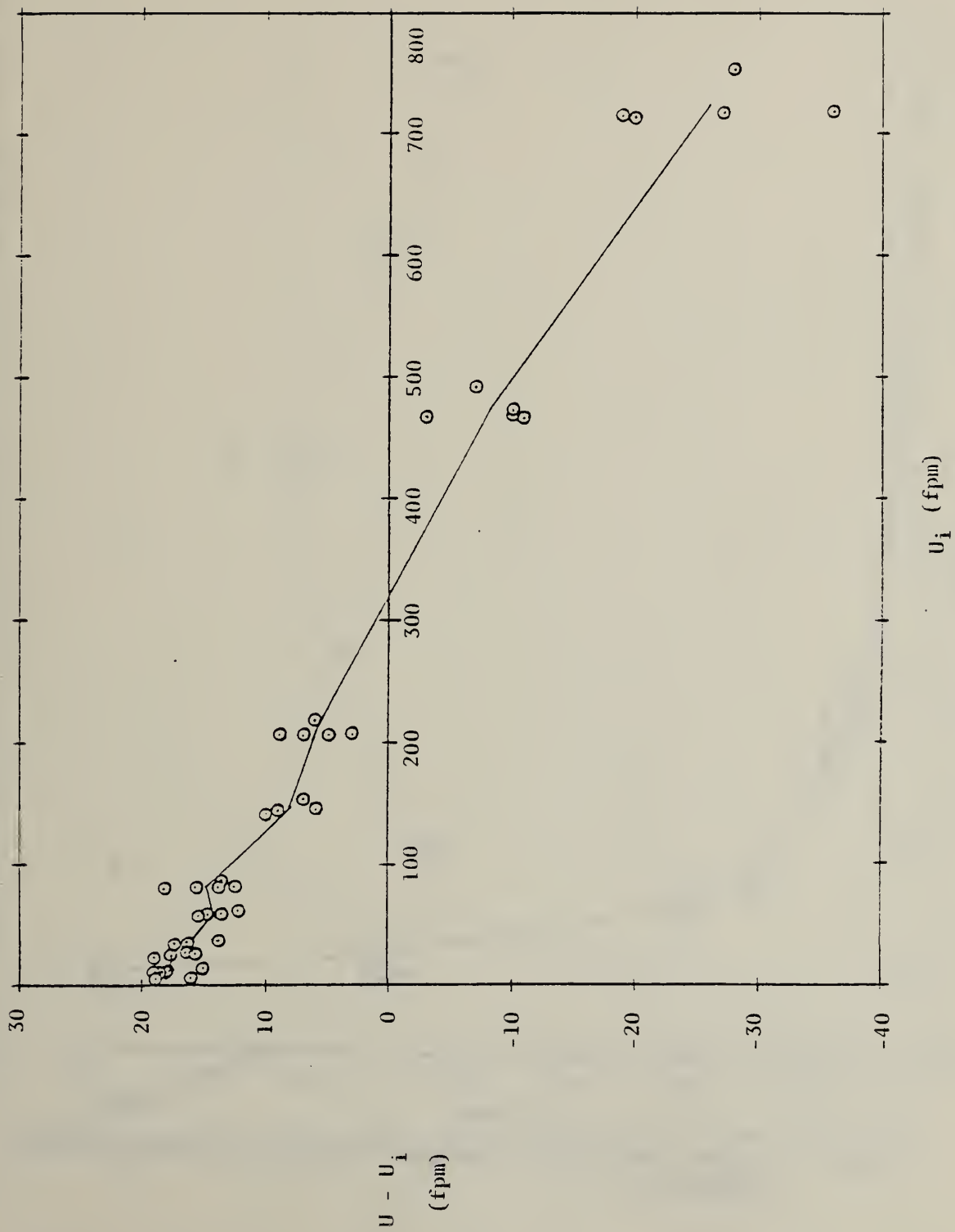


FIGURE 35. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY. INSTRUMENT B.

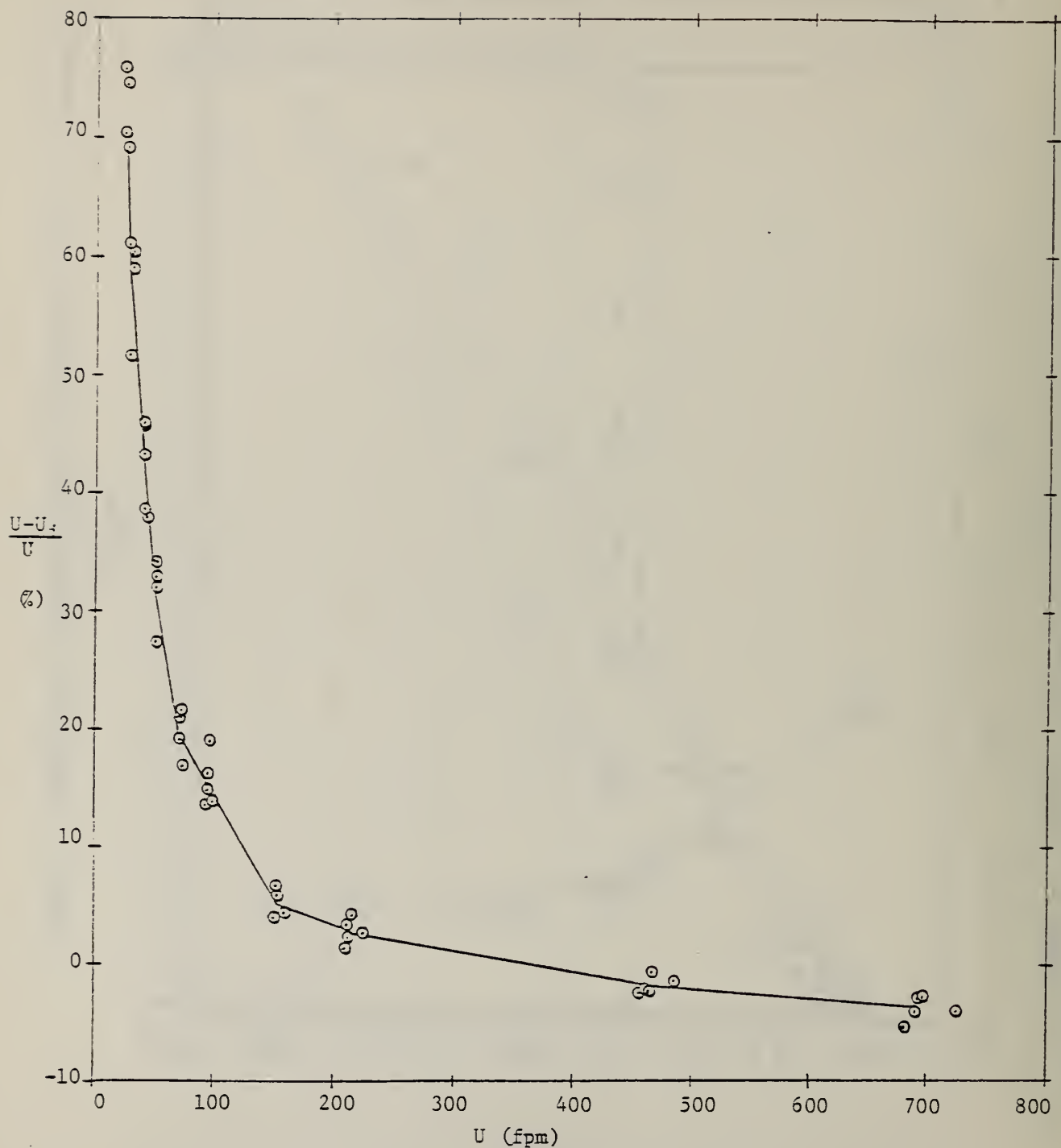


FIGURE 36. PERCENT DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY.  
INSTRUMENT B.

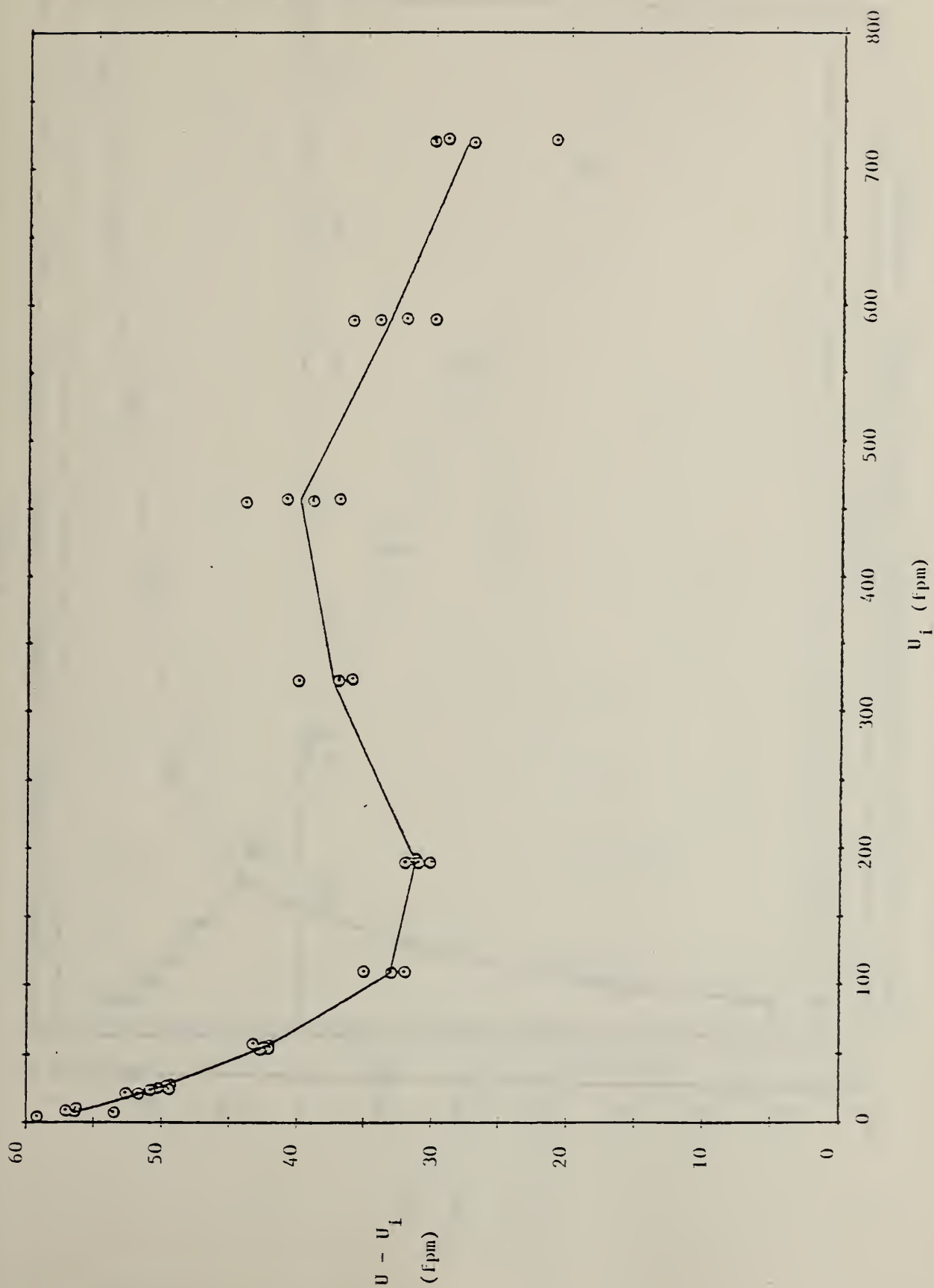


FIGURE 37. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY. INSTRUMENT C.

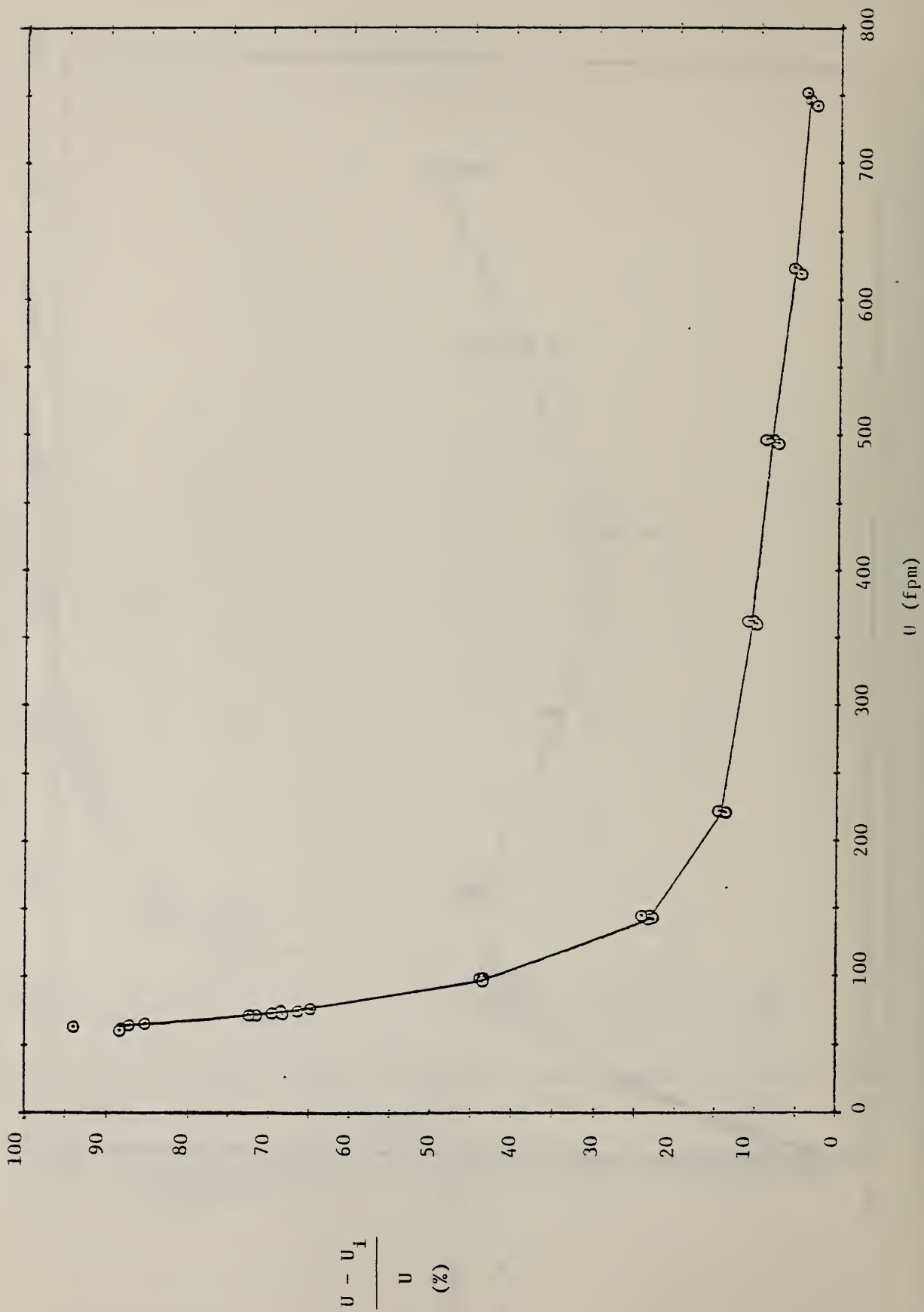


FIGURE 38. PERCENT DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY. INSTRUMENT C.

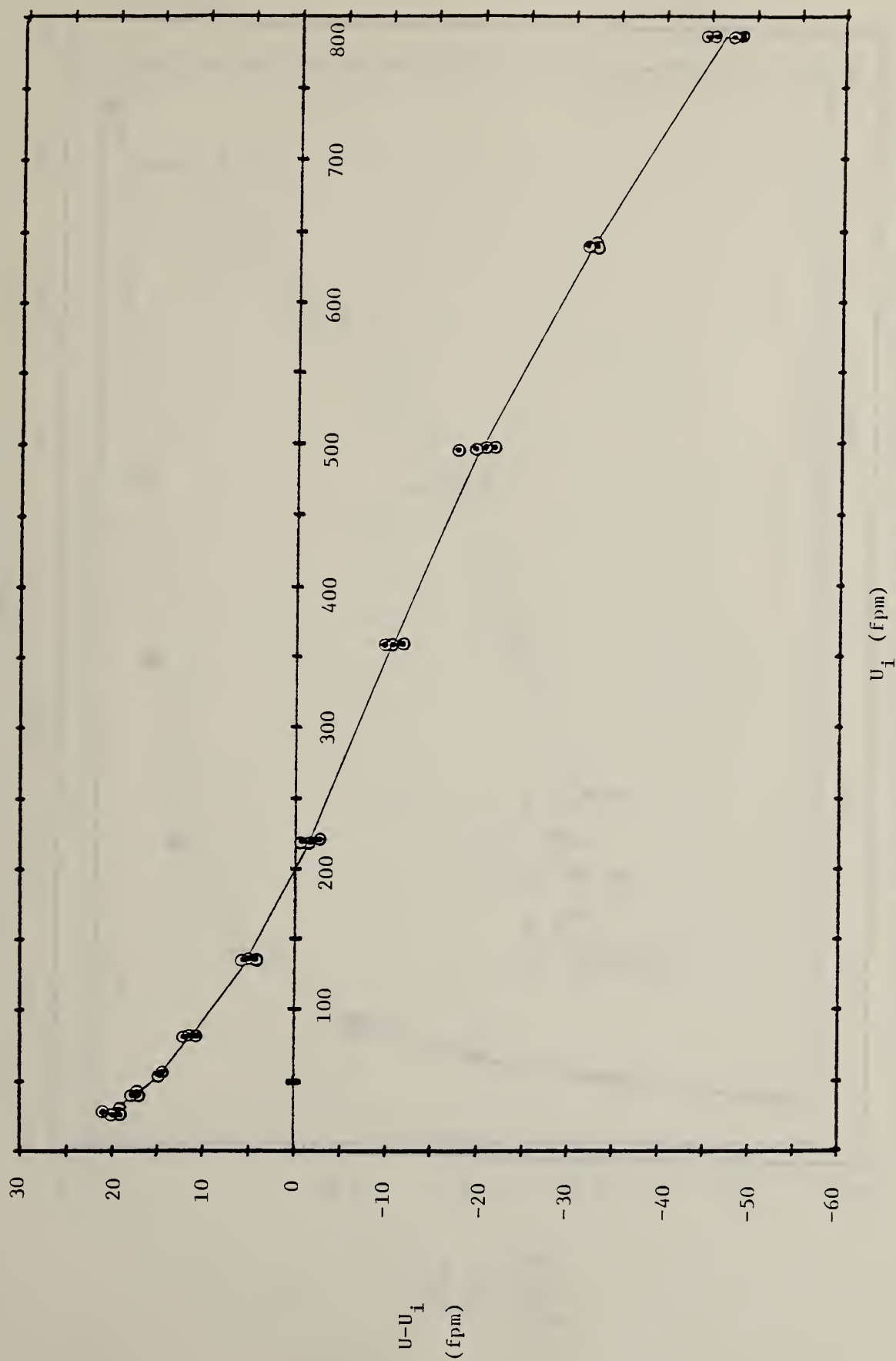


FIGURE 39. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY. INSTRUMENT D.

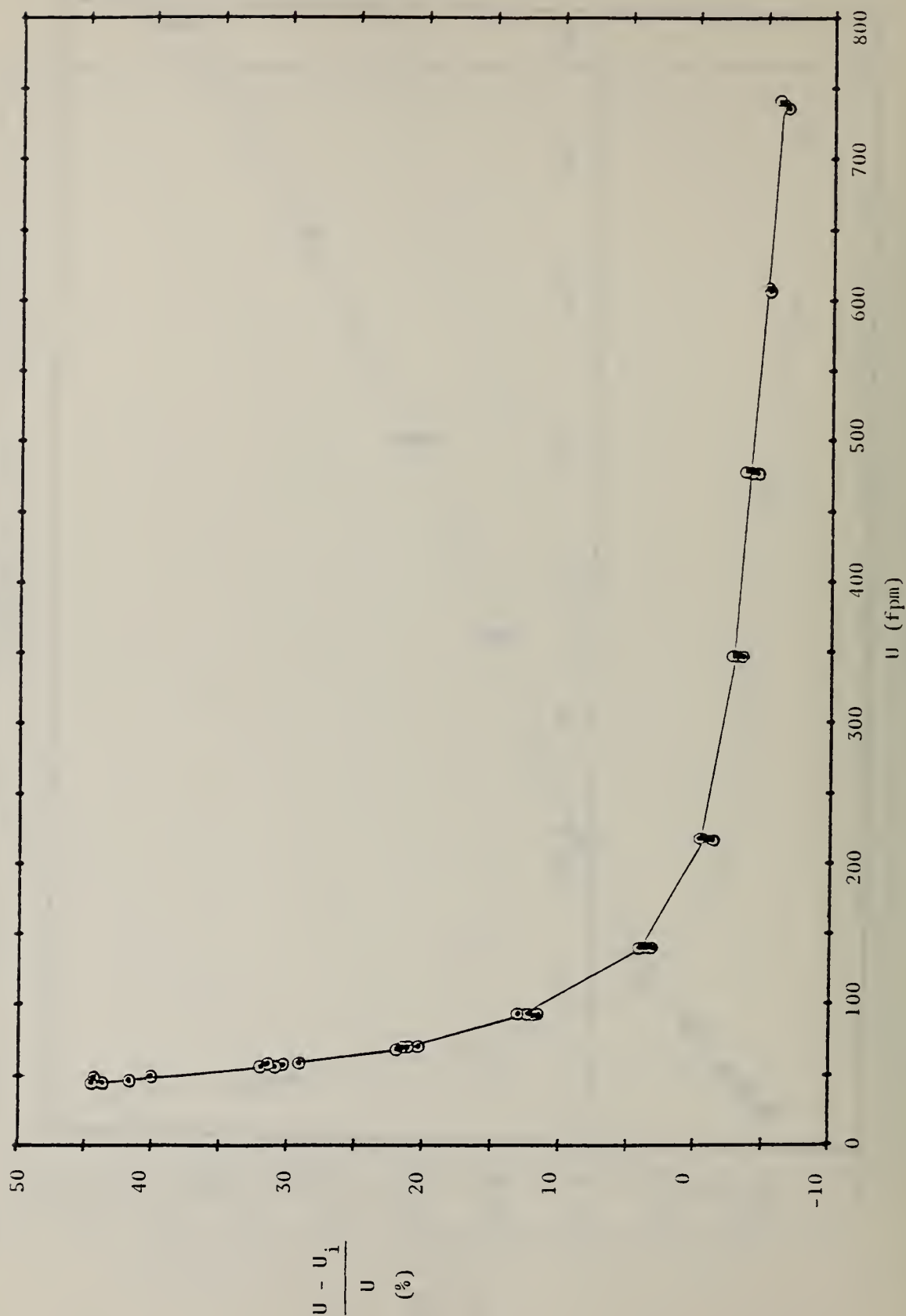


FIGURE 40. PERCENT DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY. INSTRUMENT D.

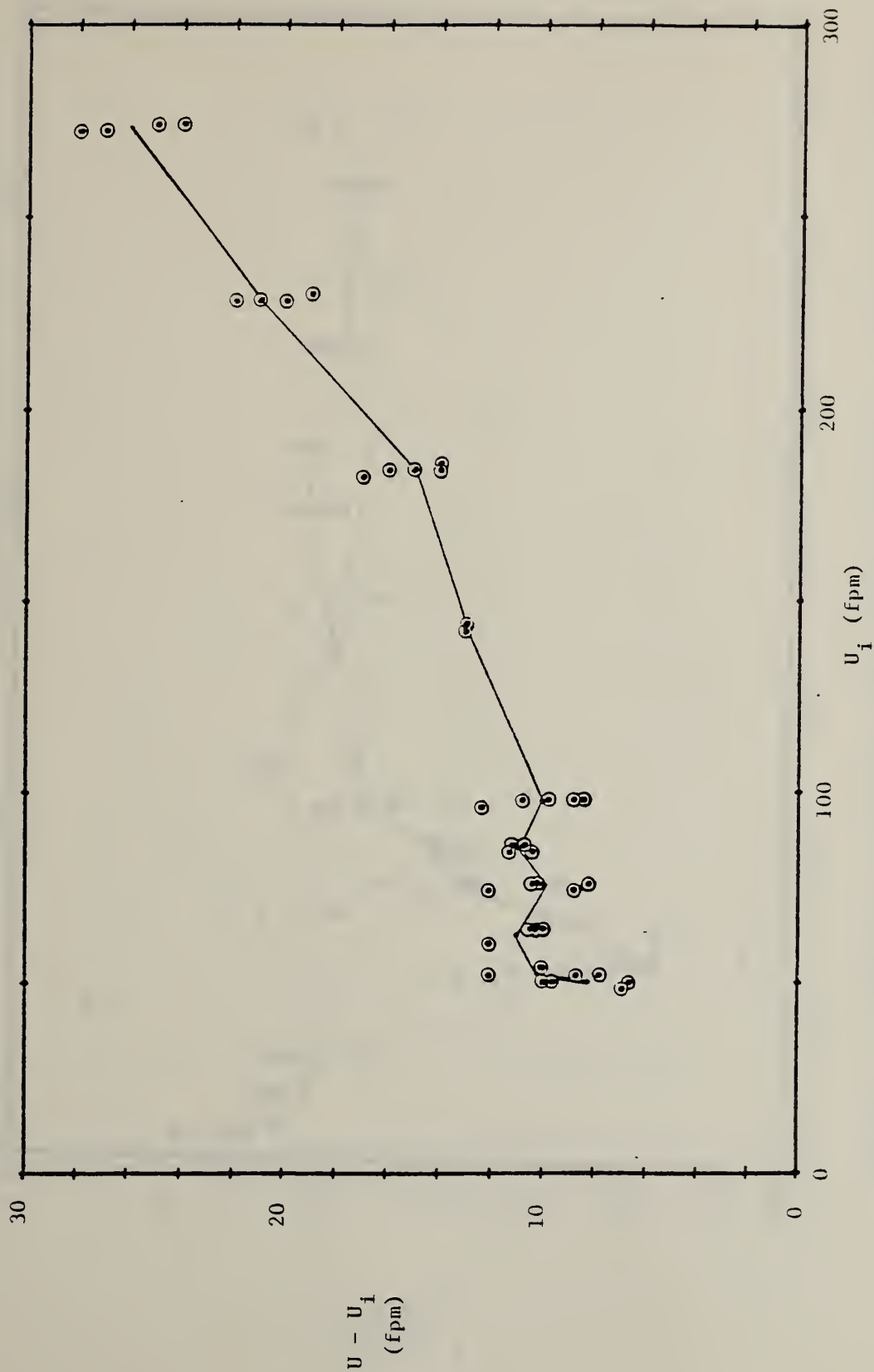


FIGURE 41. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, LOW RANGE. INSTRUMENT E.

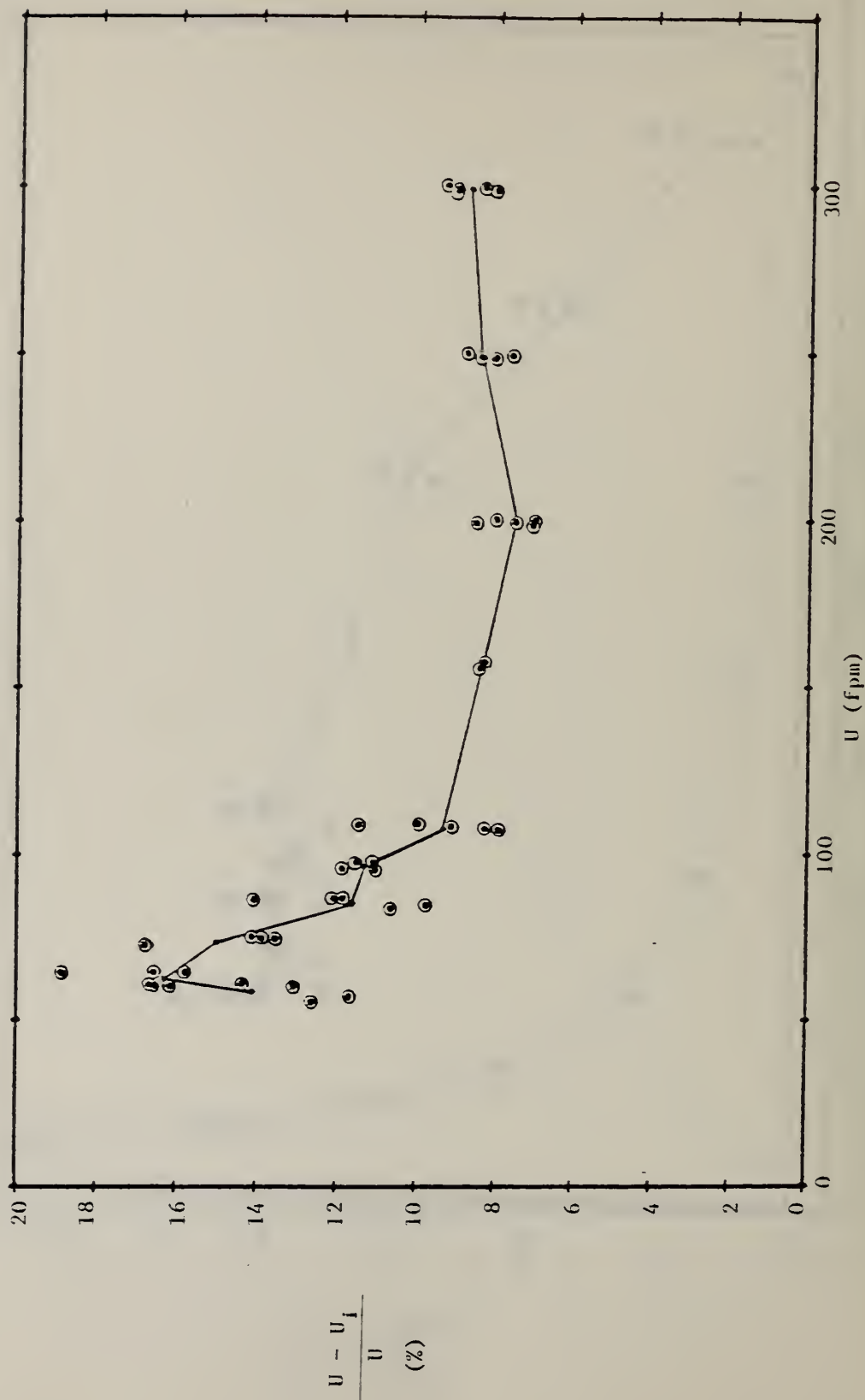


FIGURE 42. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY, LOW RANGE. INSTRUMENT E.

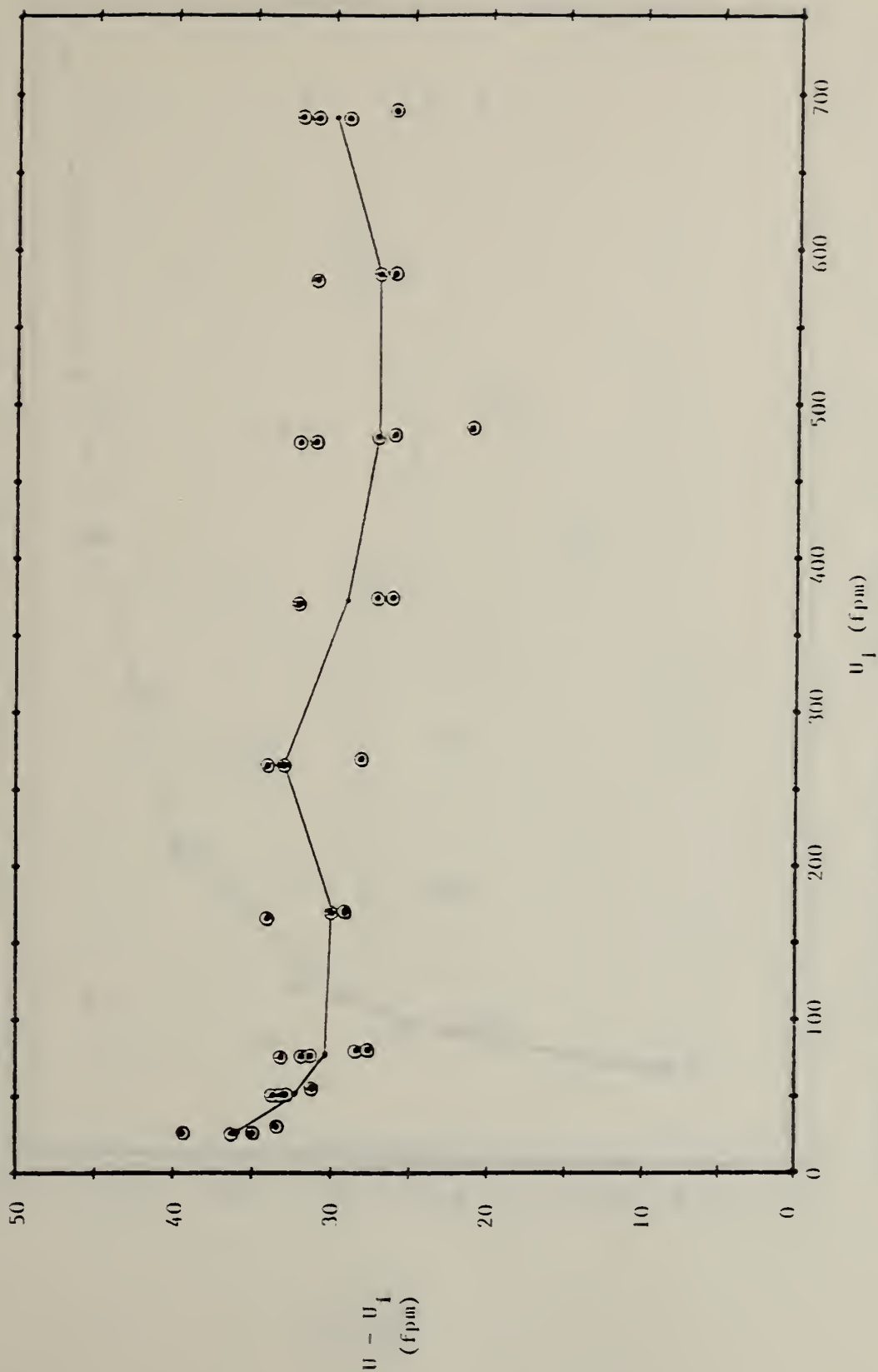


FIGURE 43. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, MEDIUM RANGE. INSTRUMENT E.

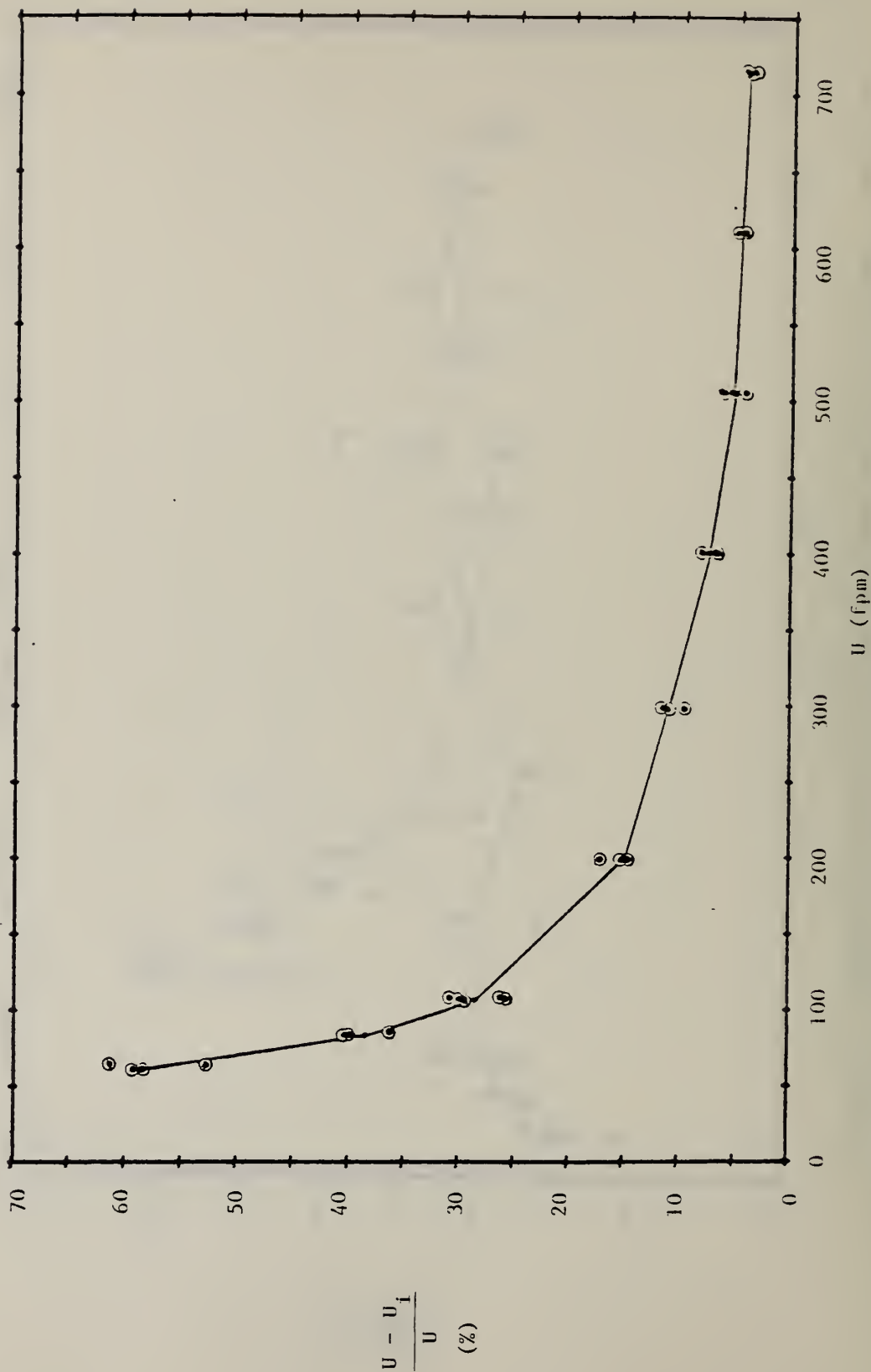


FIGURE 44. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY, MEDIUM RANGE. INSTRUMENT E.

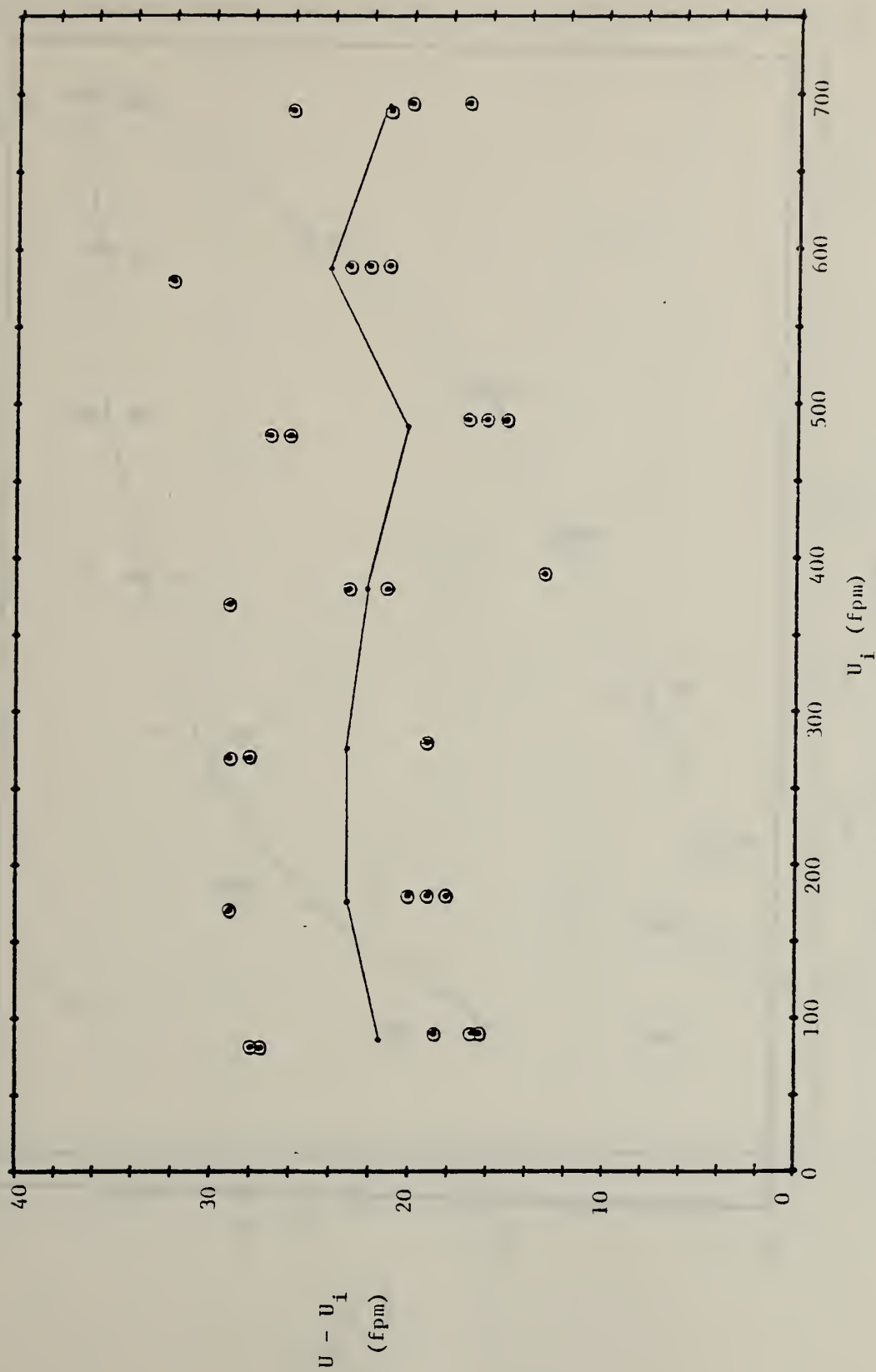


FIGURE 45. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, HIGH RANGE. INSTRUMENT E.

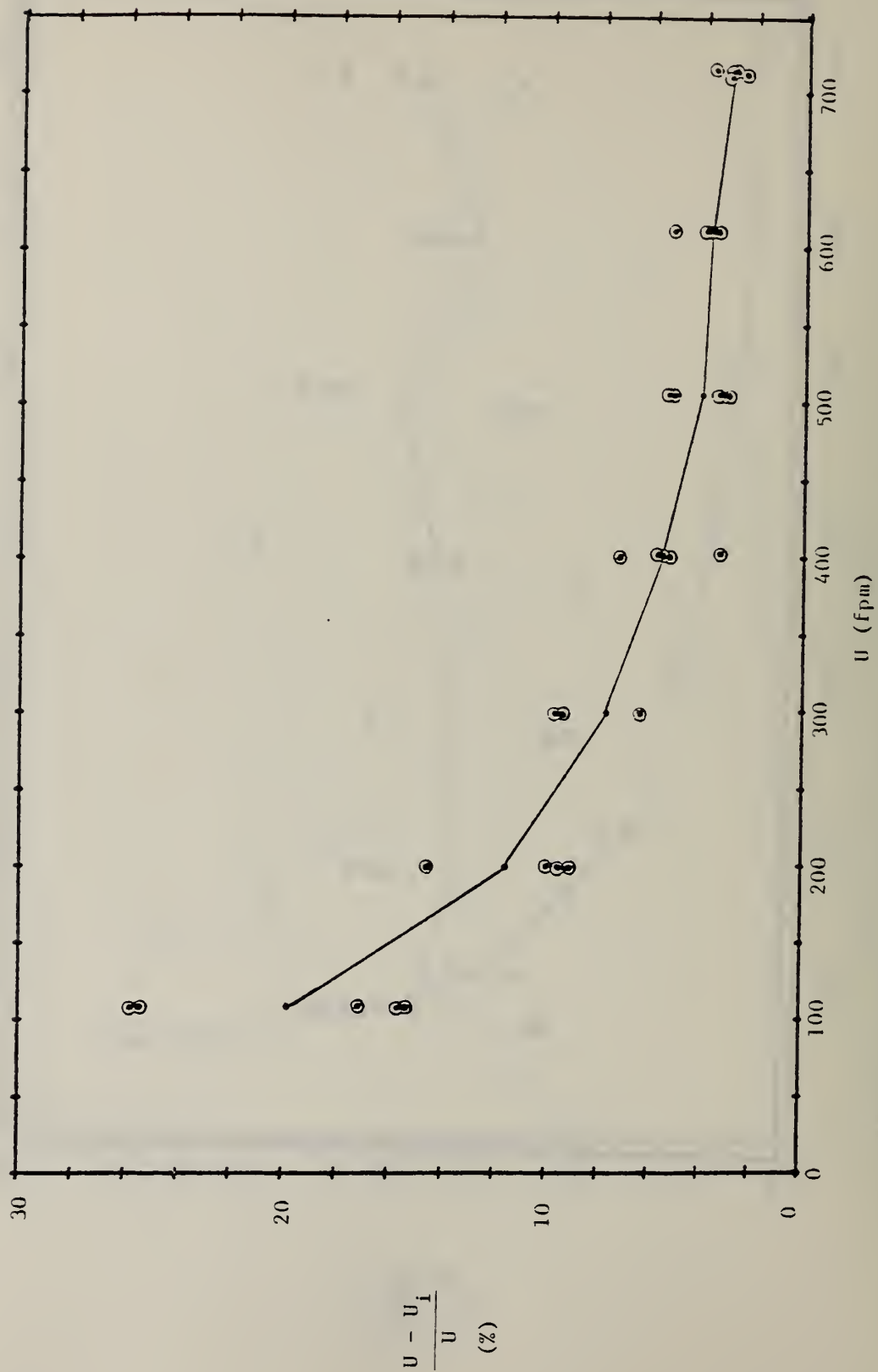


FIGURE 46. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY, HIGH RANGE. INSTRUMENT E.

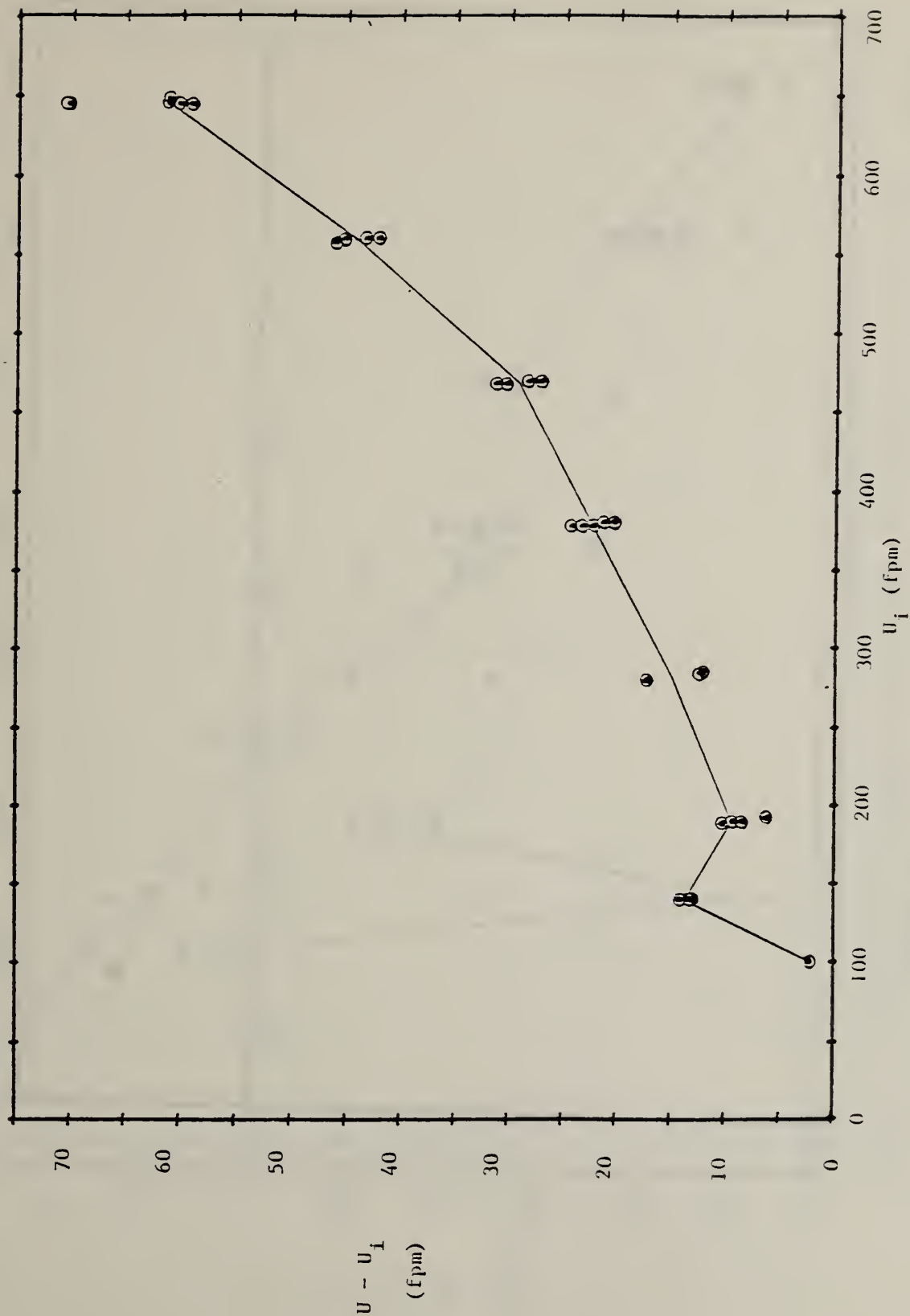


FIGURE 47. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR PITOT PROBE, LOW RANGE, INSTRUMENT F.

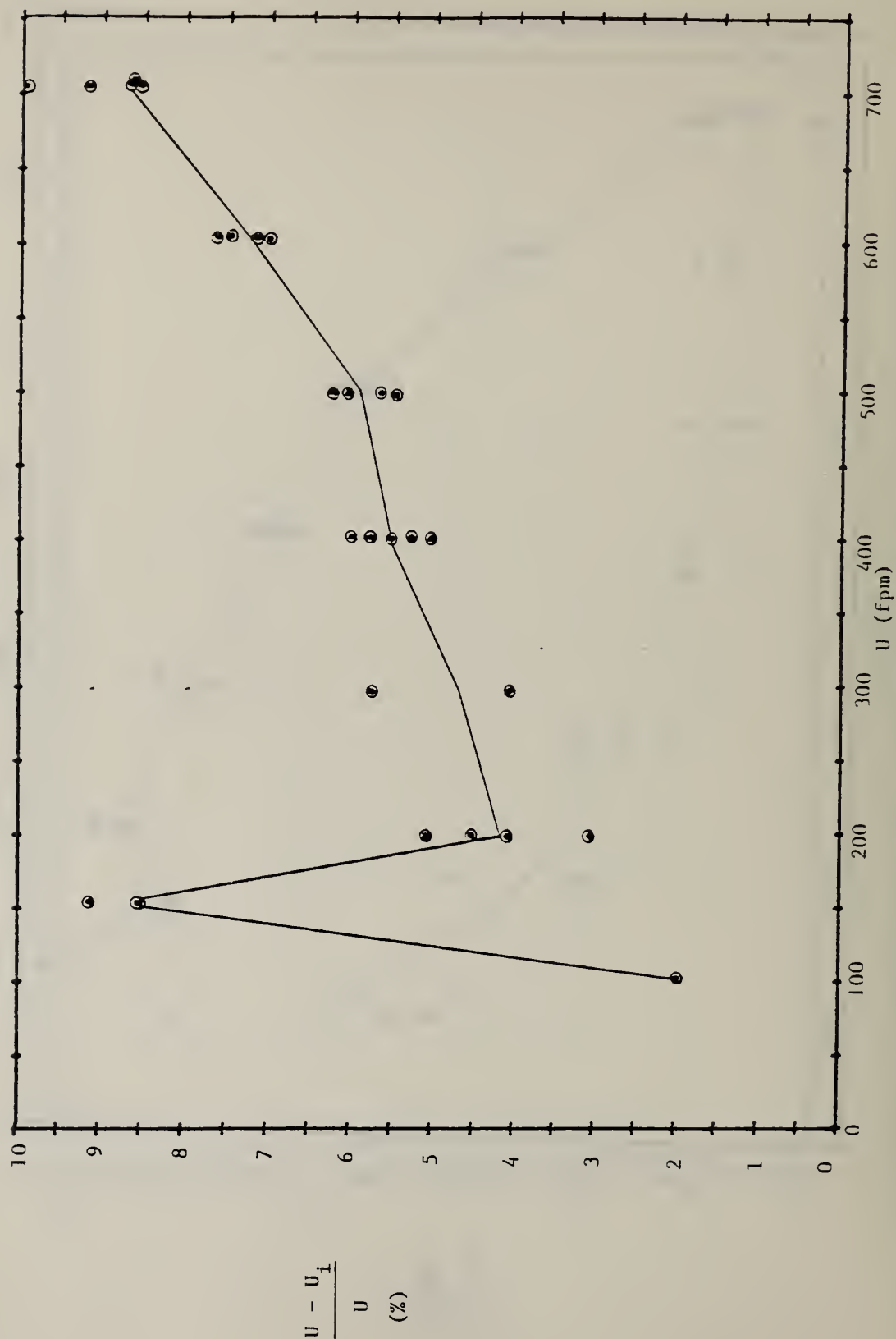


FIGURE 48. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR PITOT PROBE, LOW RANGE. INSTRUMENT F.

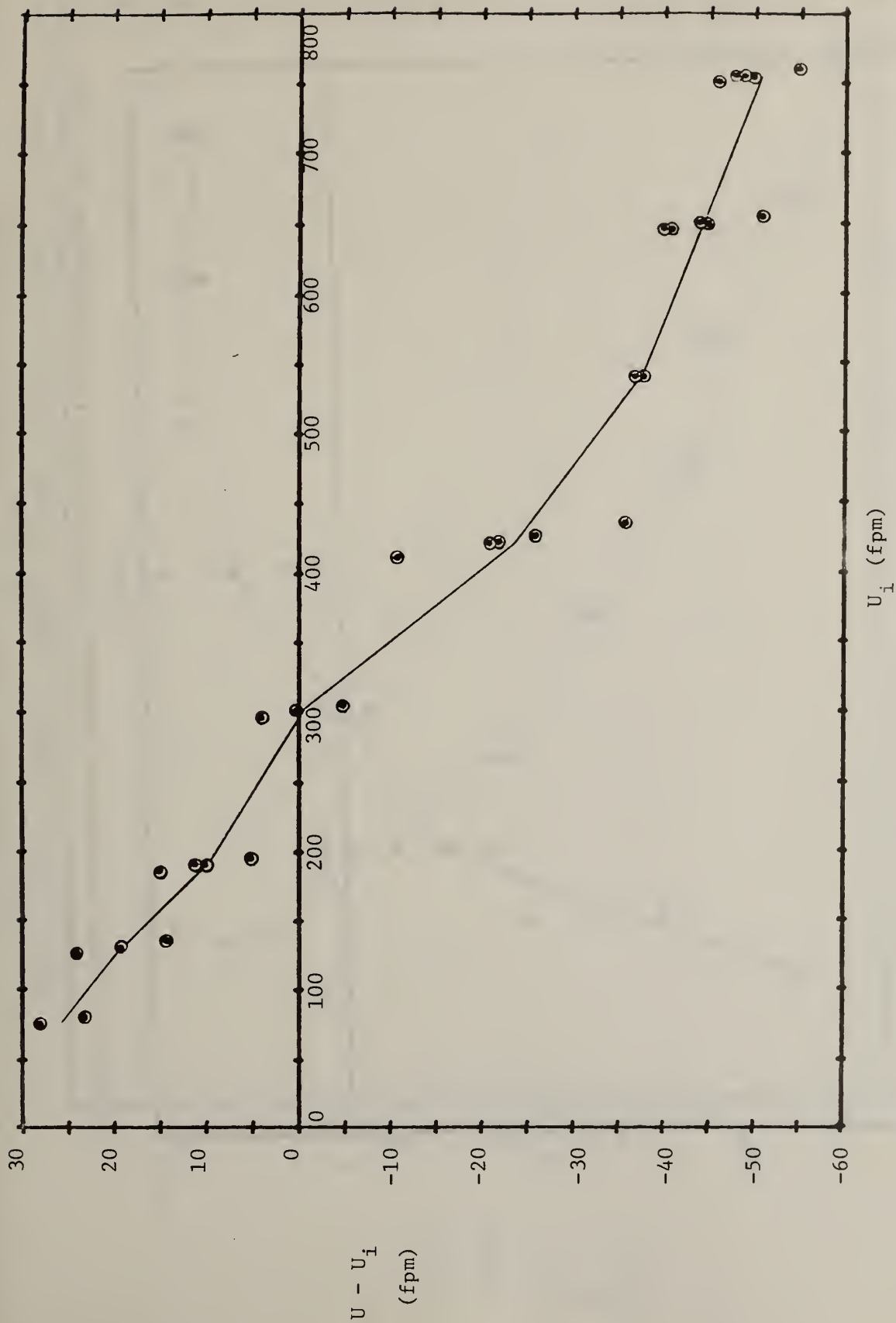


FIGURE 49. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE.  
INSTRUMENT F.

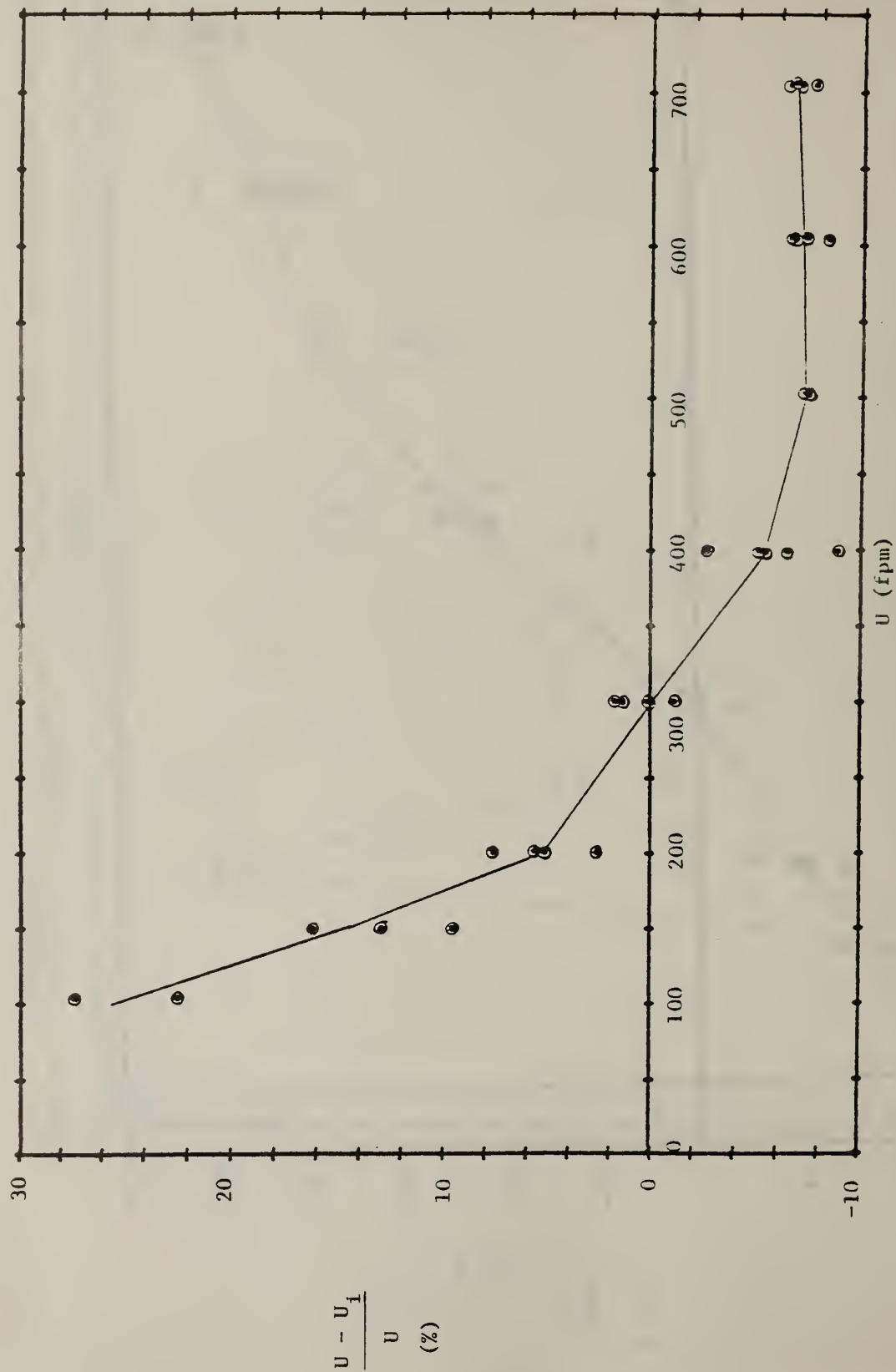


FIGURE 50. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE. INSTRUMENT F.

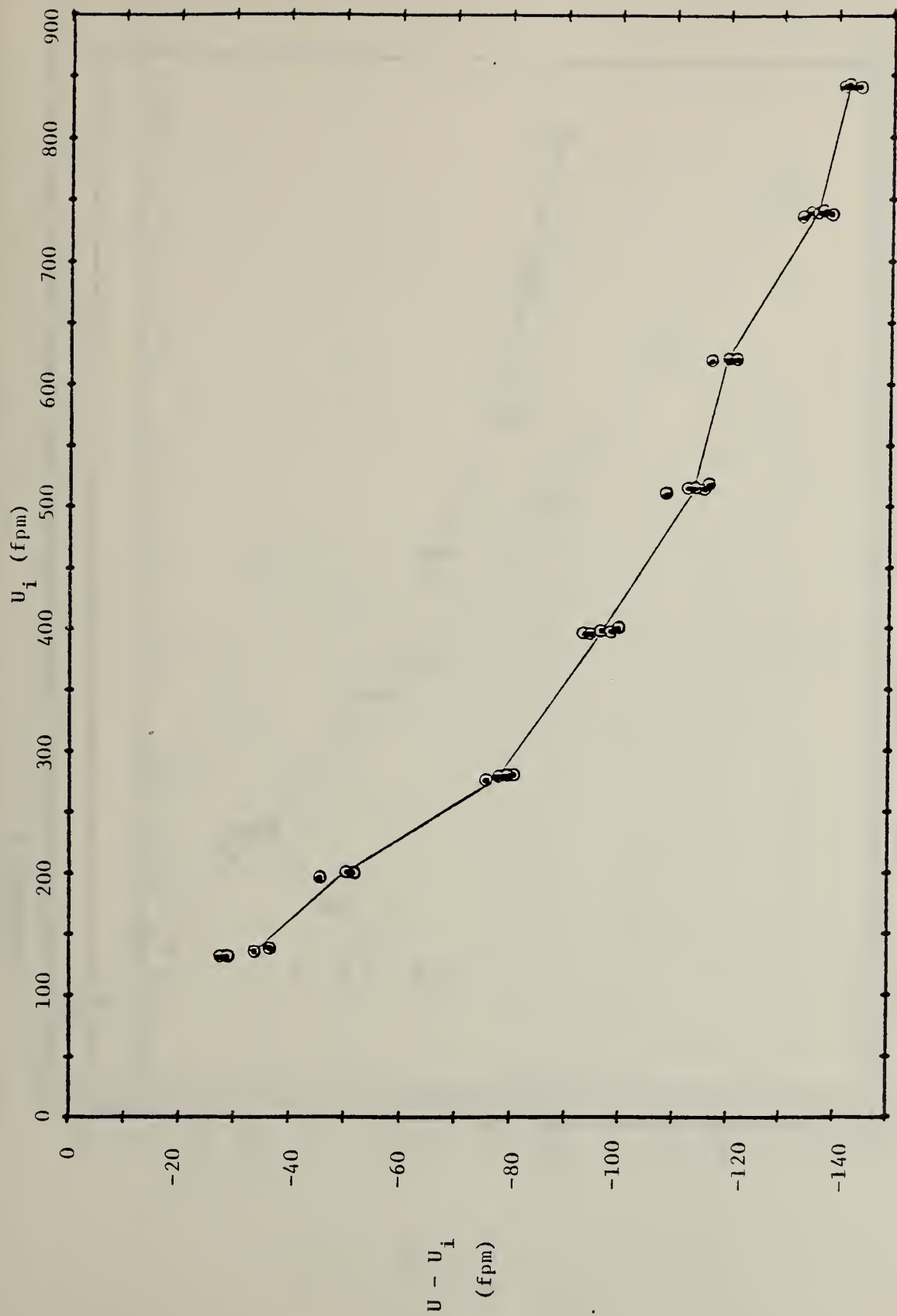


FIGURE 51. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE.  
INSTRUMENT F.

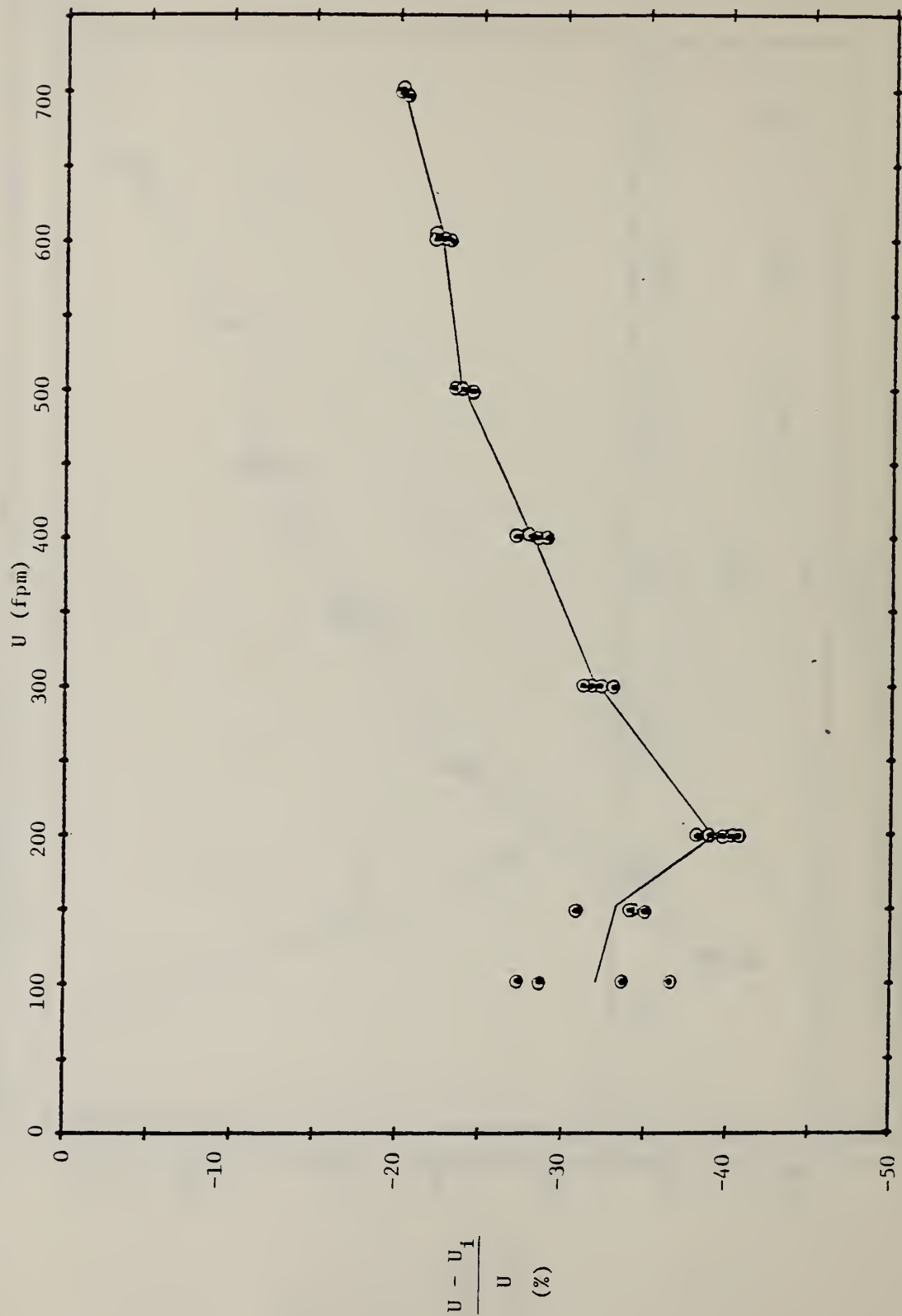


FIGURE 52. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE. INSTRUMENT F.

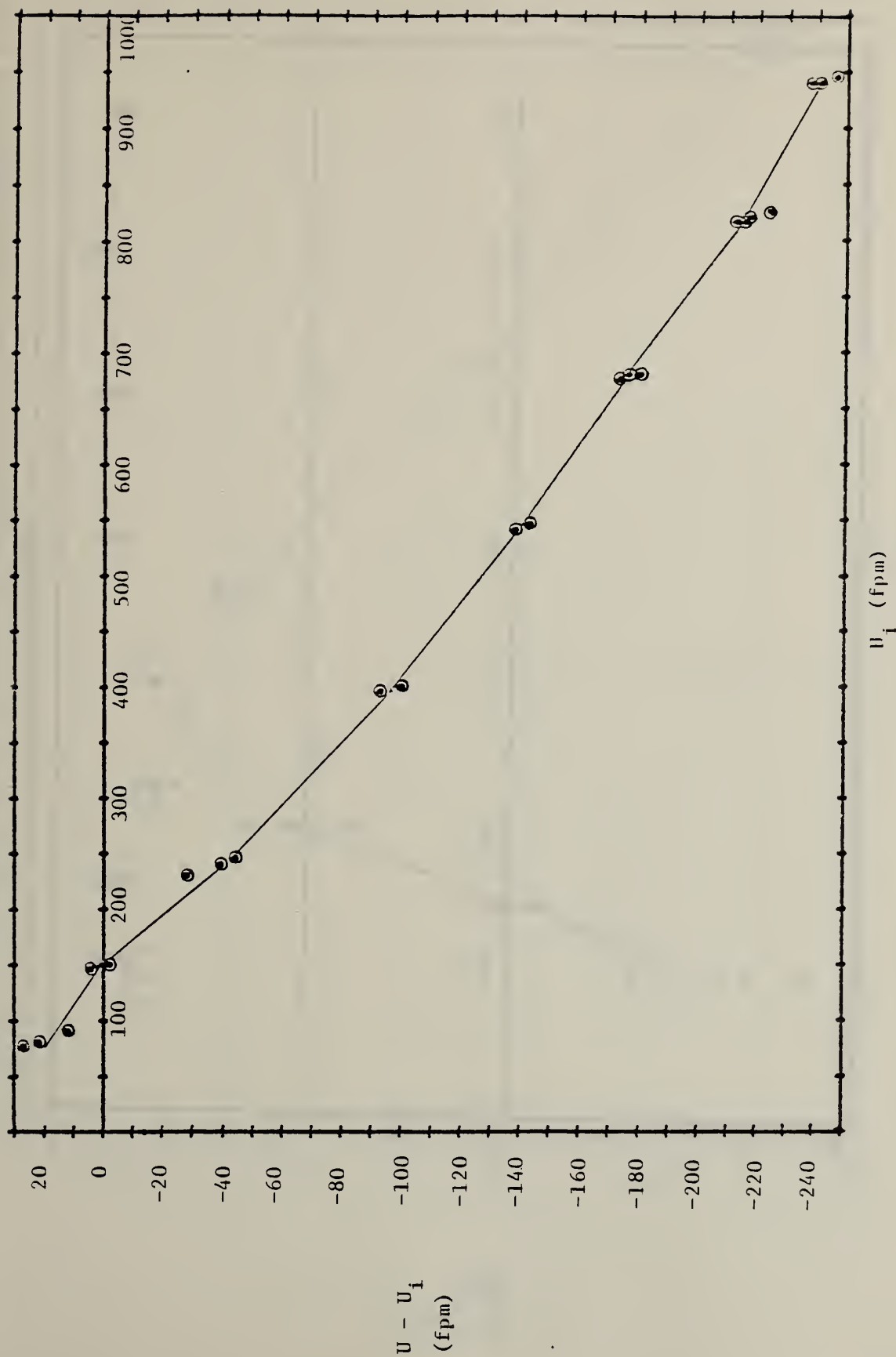


FIGURE 53. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE. INSTRUMENT F.

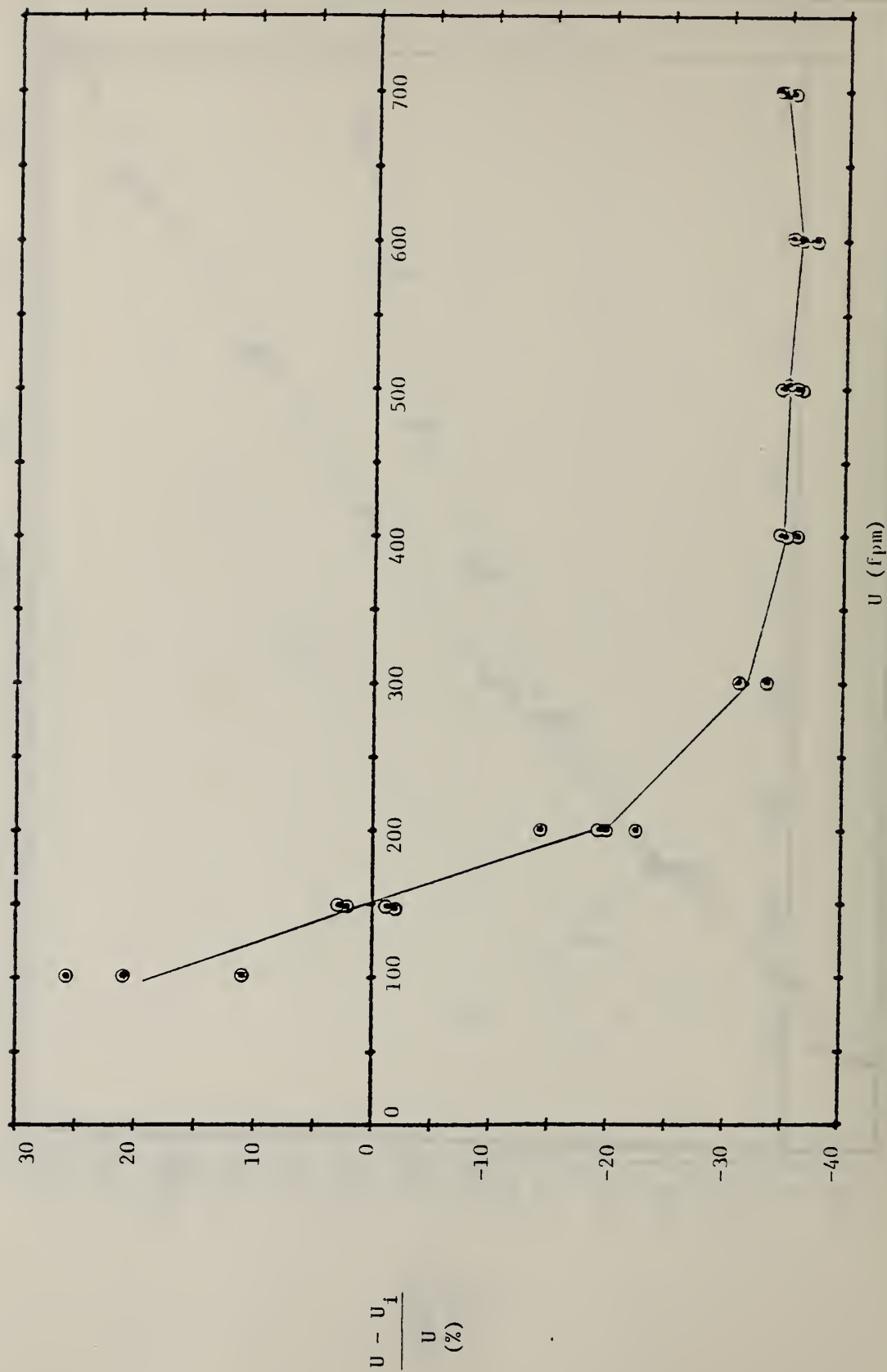


FIGURE 54. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE. INSTRUMENT P.

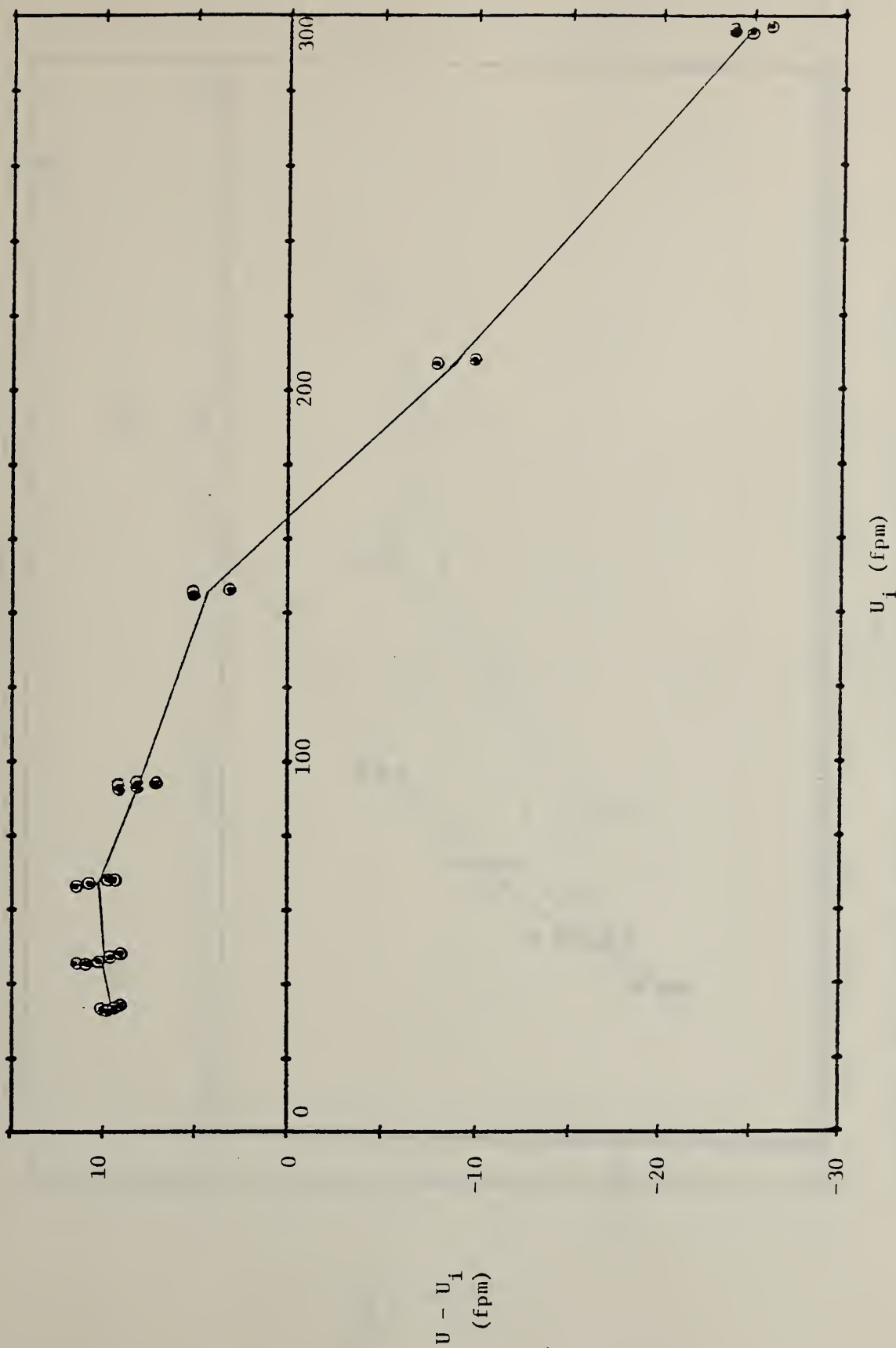


FIGURE 55. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY FOR LOW VELOCITY PROBE.

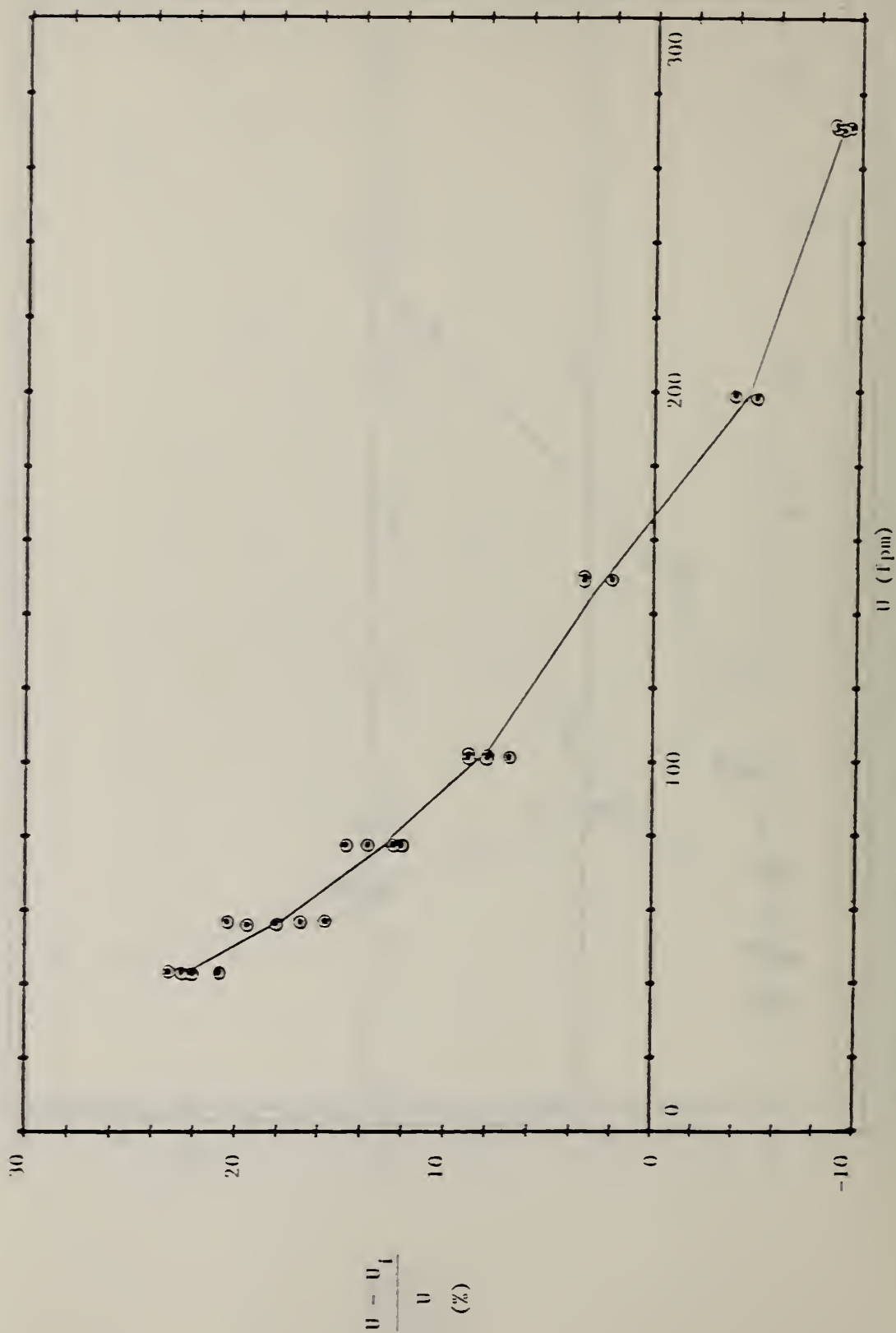


FIGURE 56. PERCENT DEVIATION OF INDICATED FROM TRUE VELOCITY FOR LOW VELOCITY PROBE.  
INSTRUMENT P.

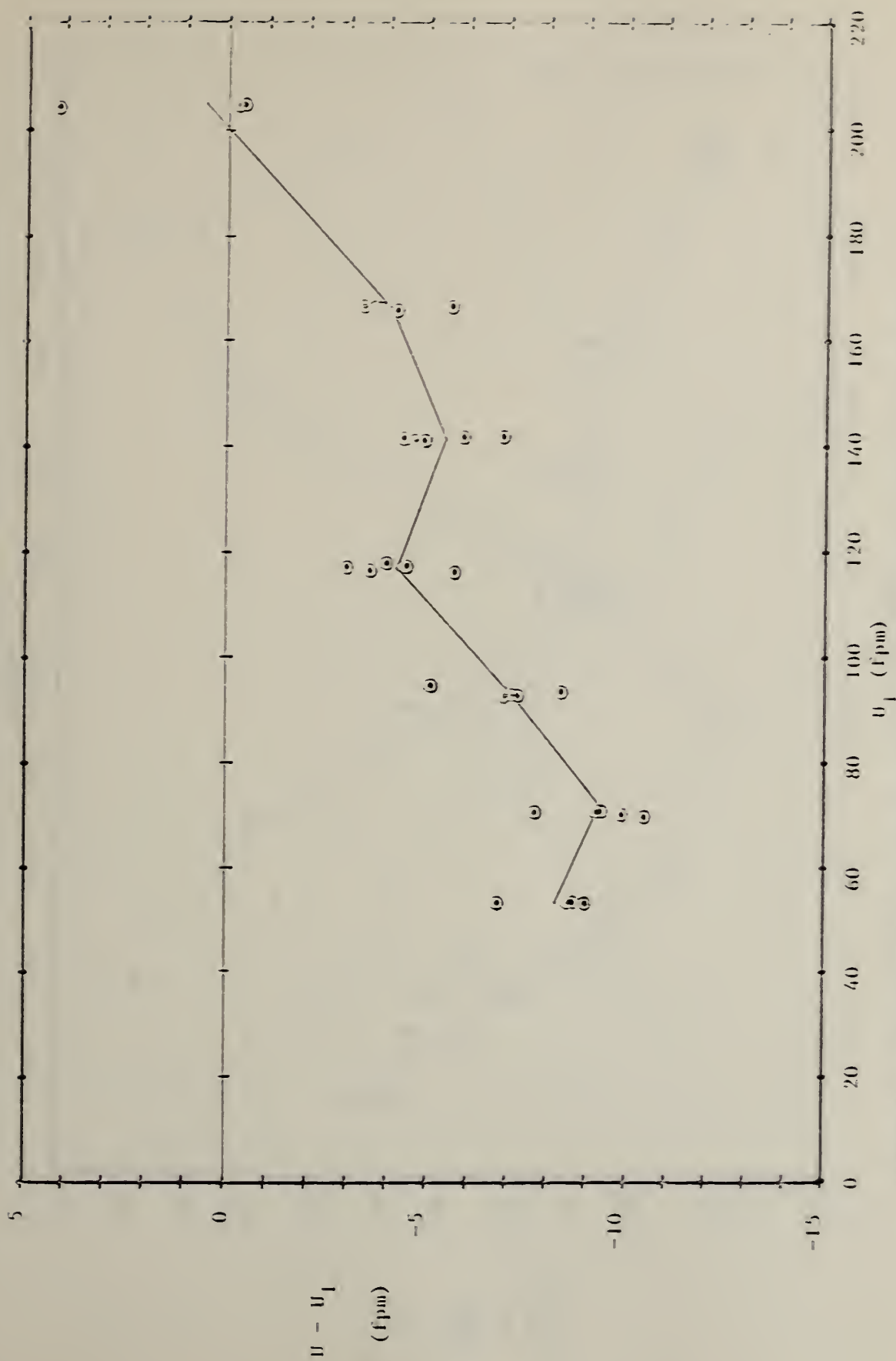


FIGURE 57. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, LOW RANGE.  
INSTRUMENT G.

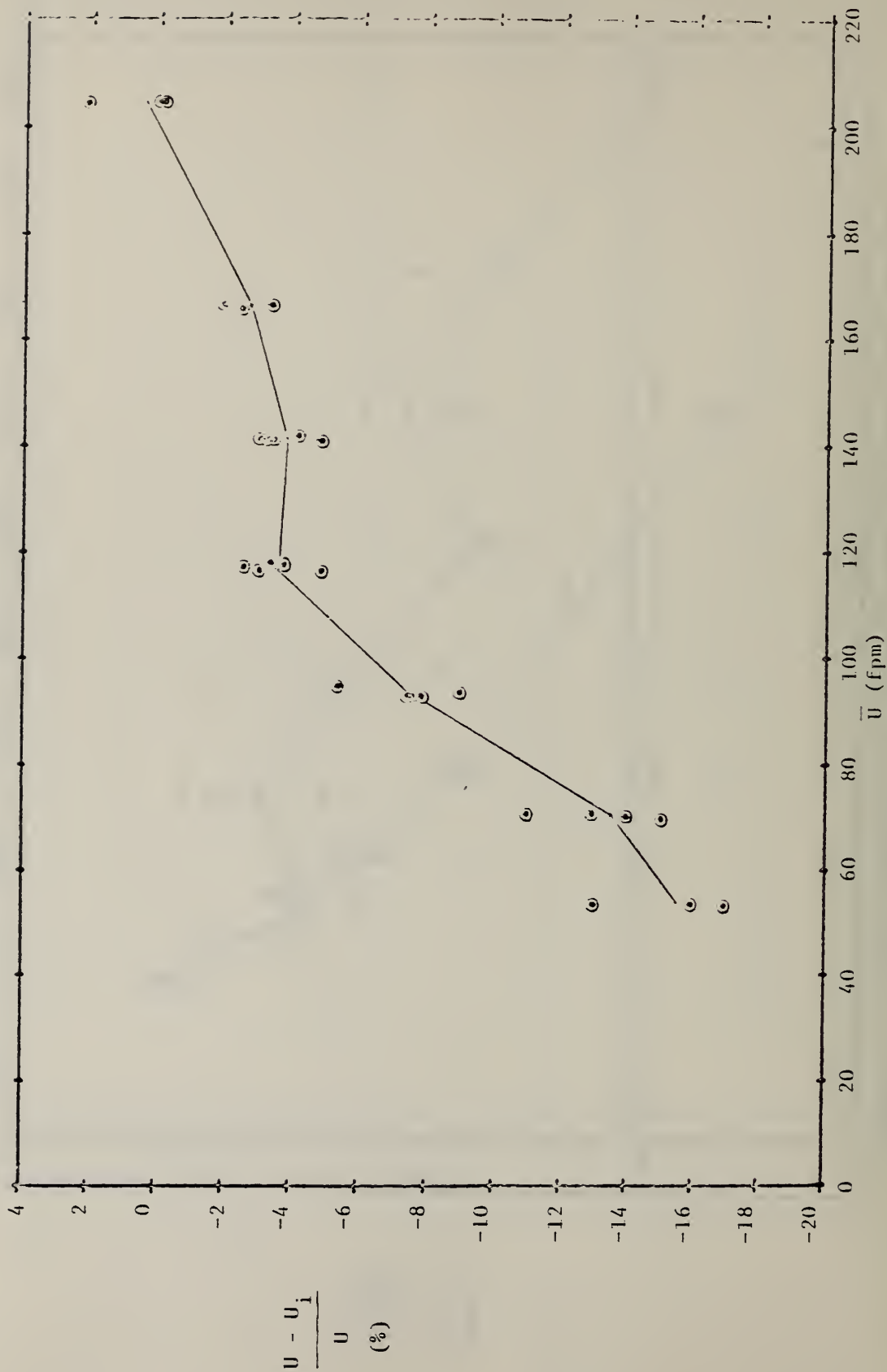


FIGURE 58. PERCENT DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, LOW RANGE.  
INSTRUMENT G.

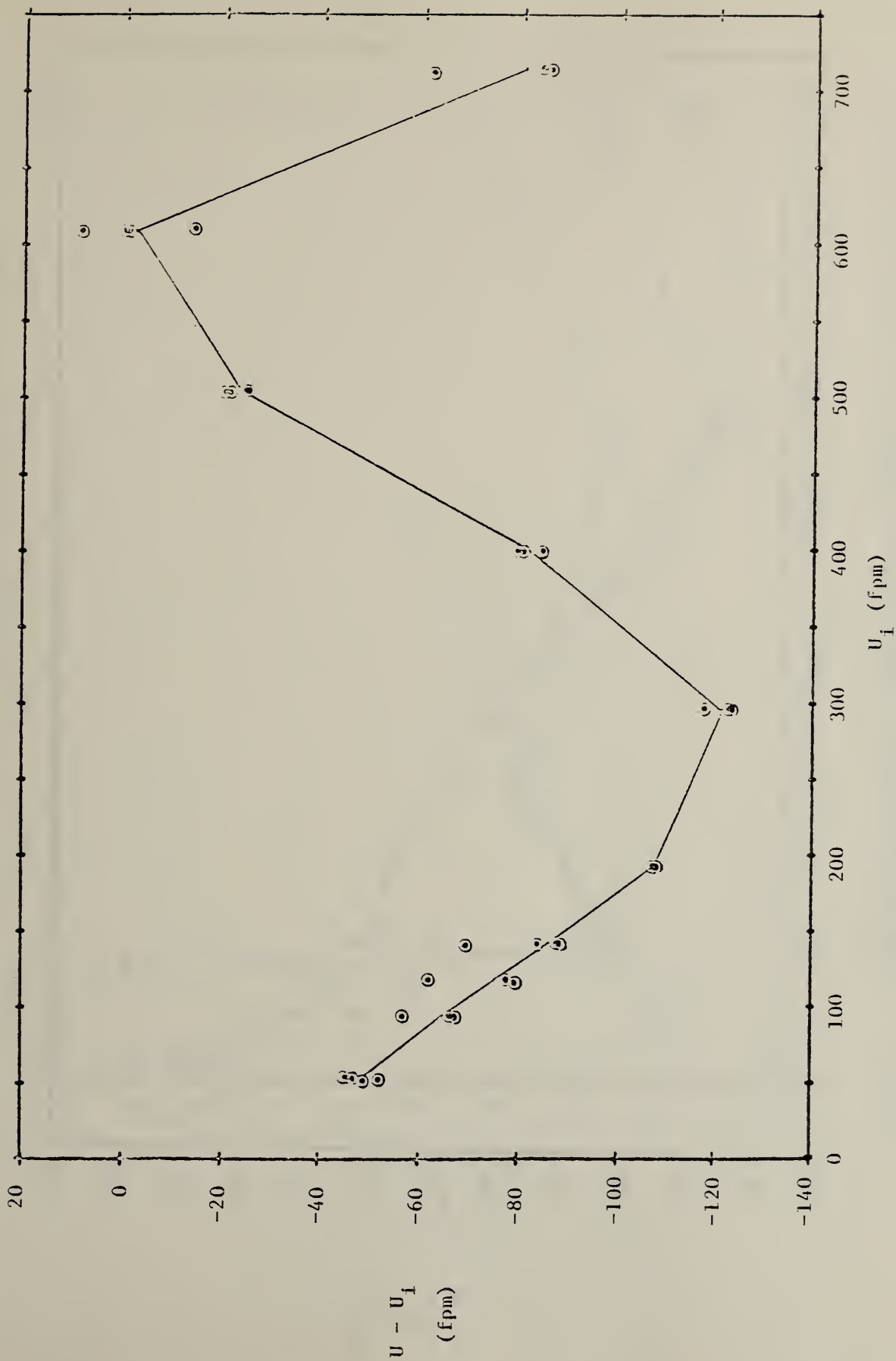


FIGURE 59. DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, HIGH RANGE.  
INSTRUMENT C.

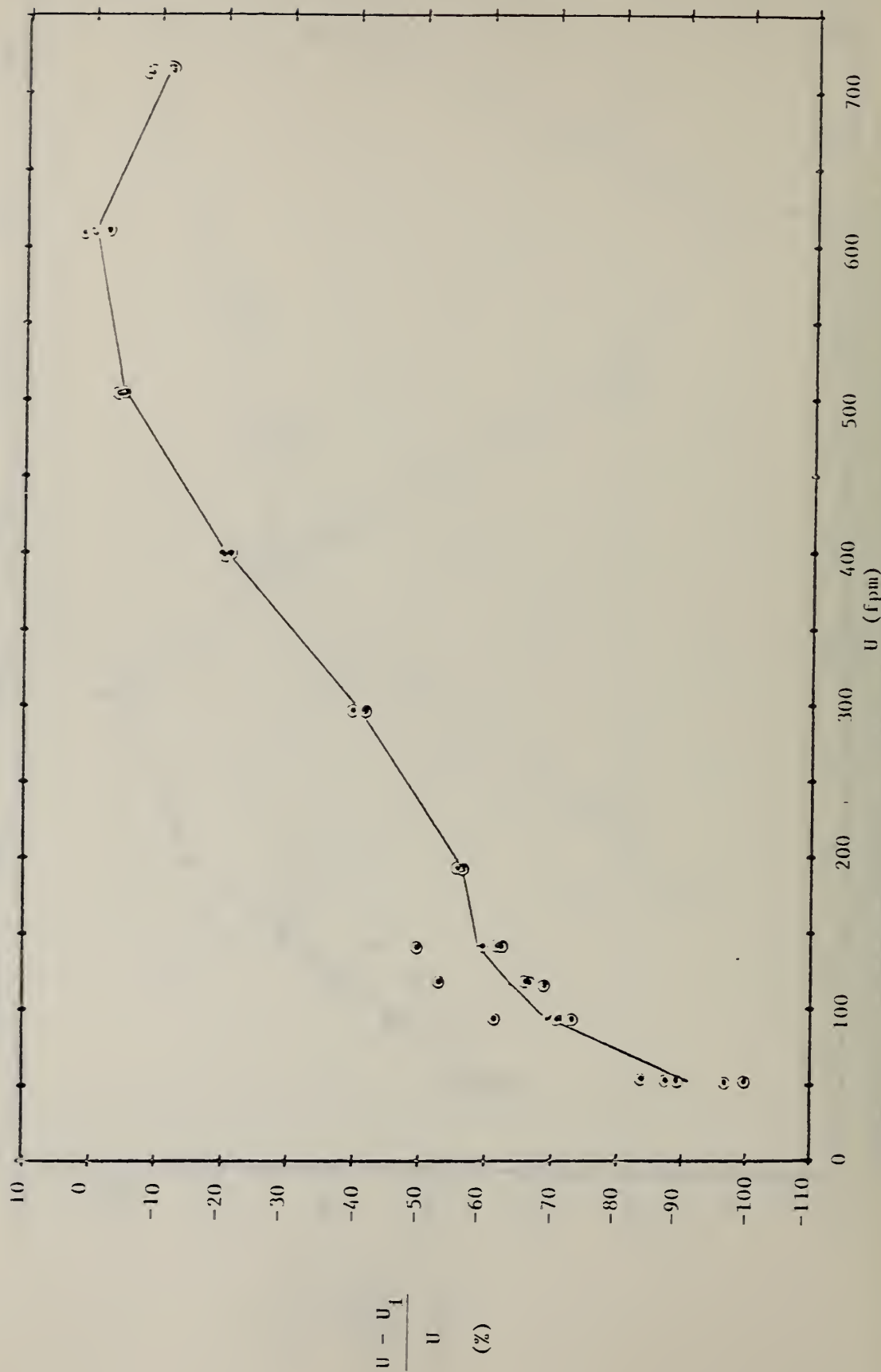


FIGURE 60. PERCENT DEVIATION OF INDICATED VELOCITY FROM TRUE VELOCITY, HIGH RANGE.  
INSTRUMENT G.

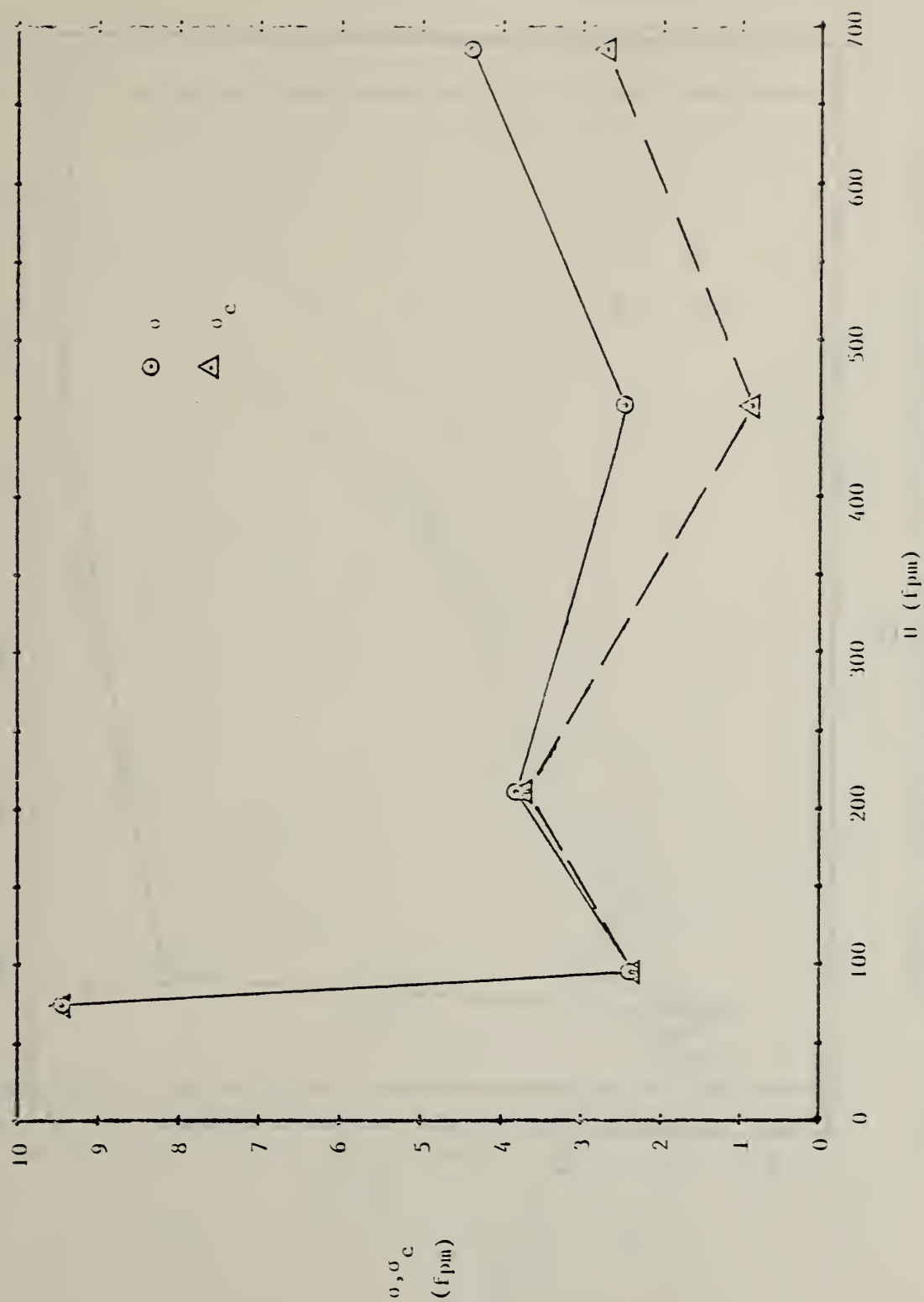


FIGURE 61. STANDARD DEVIATION AND CORRECTED STANDARD DEVIATION IN TERMS OF TRUE VELOCITY.  
INSTRUMENT A.

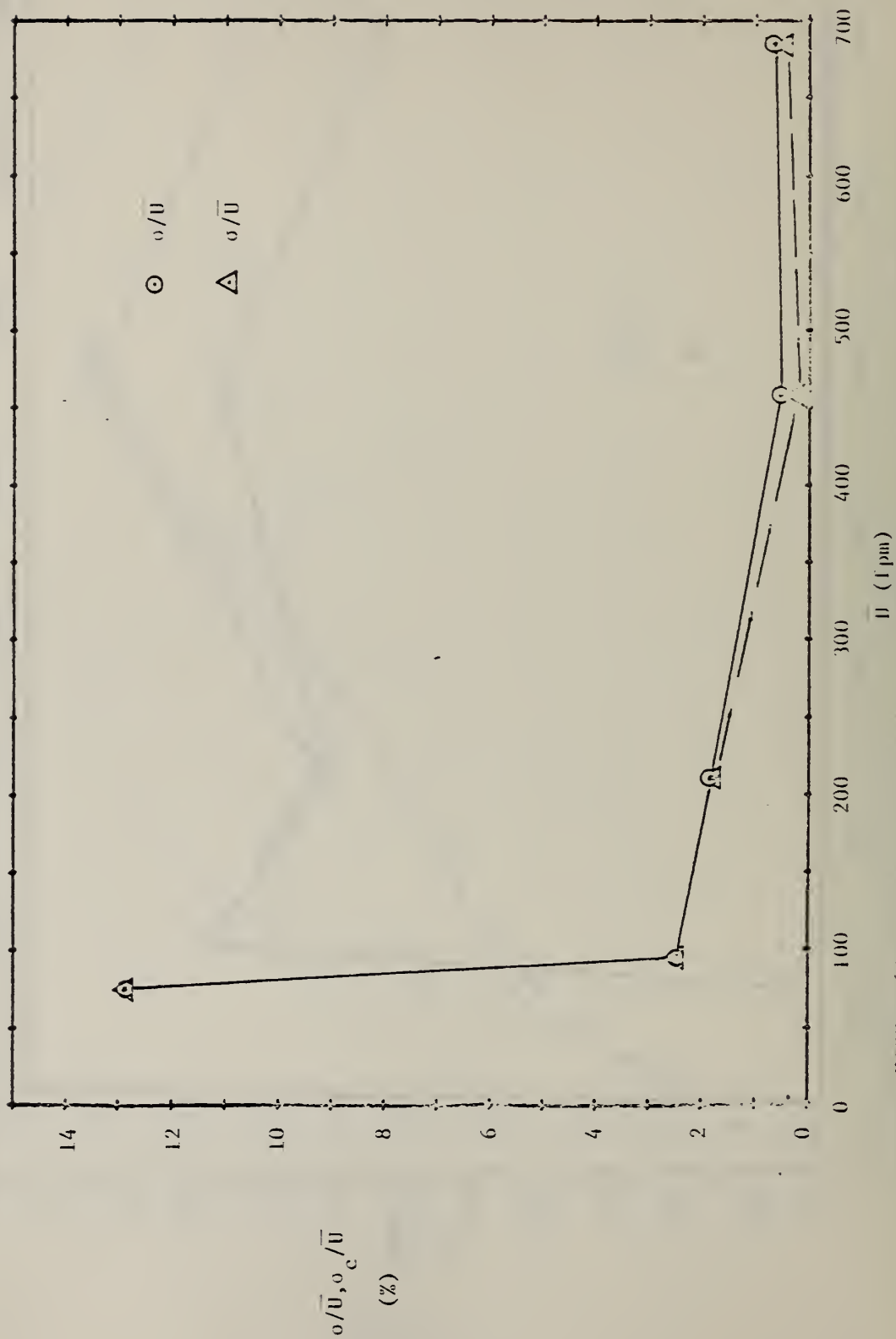


FIGURE 62.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN TRUE VELOCITY. INSTRUMENT A.

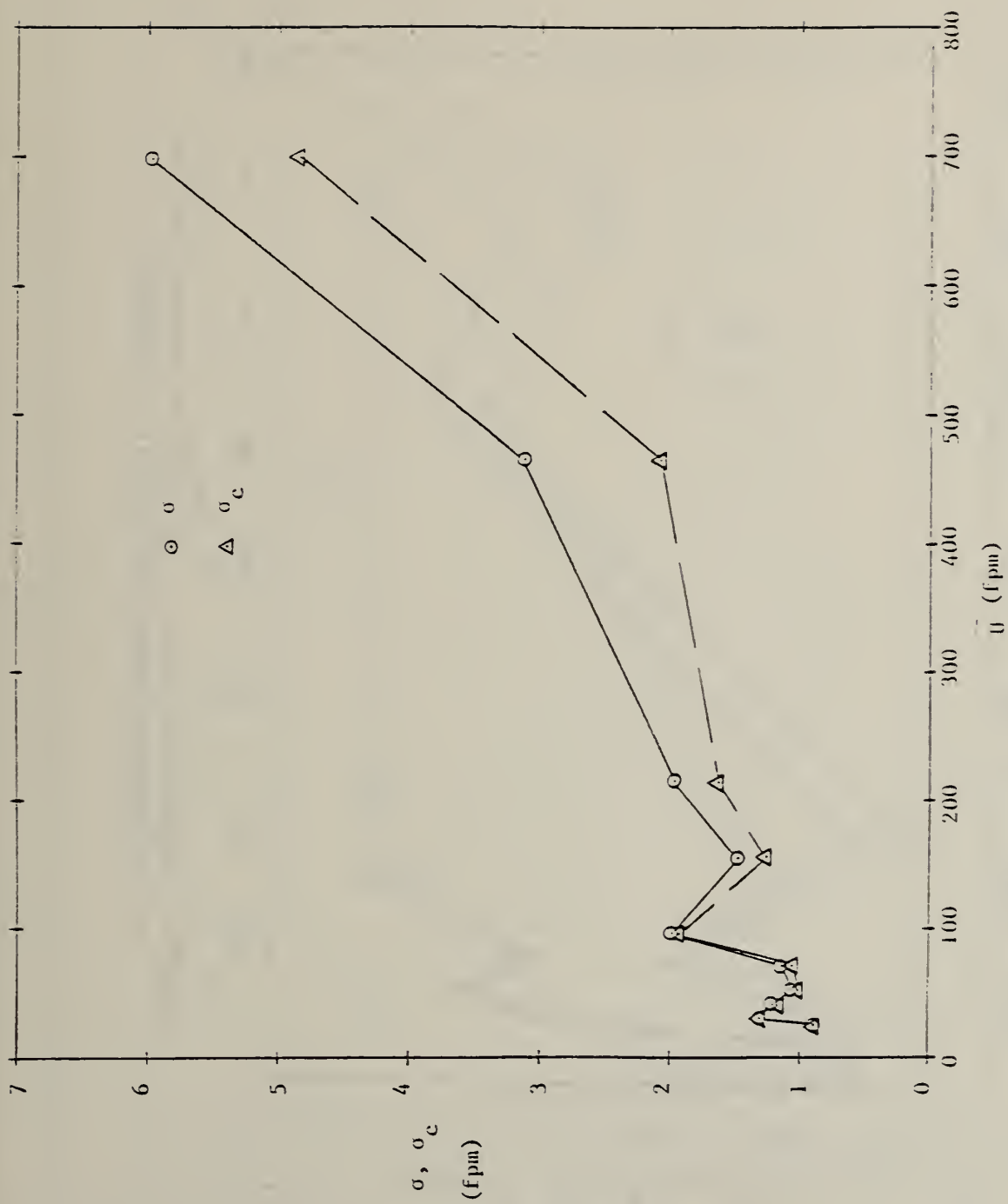


FIGURE 63. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION  $\sigma_c$ , IN TERMS OF TRUE VELOCITY. INSTRUMENT B.

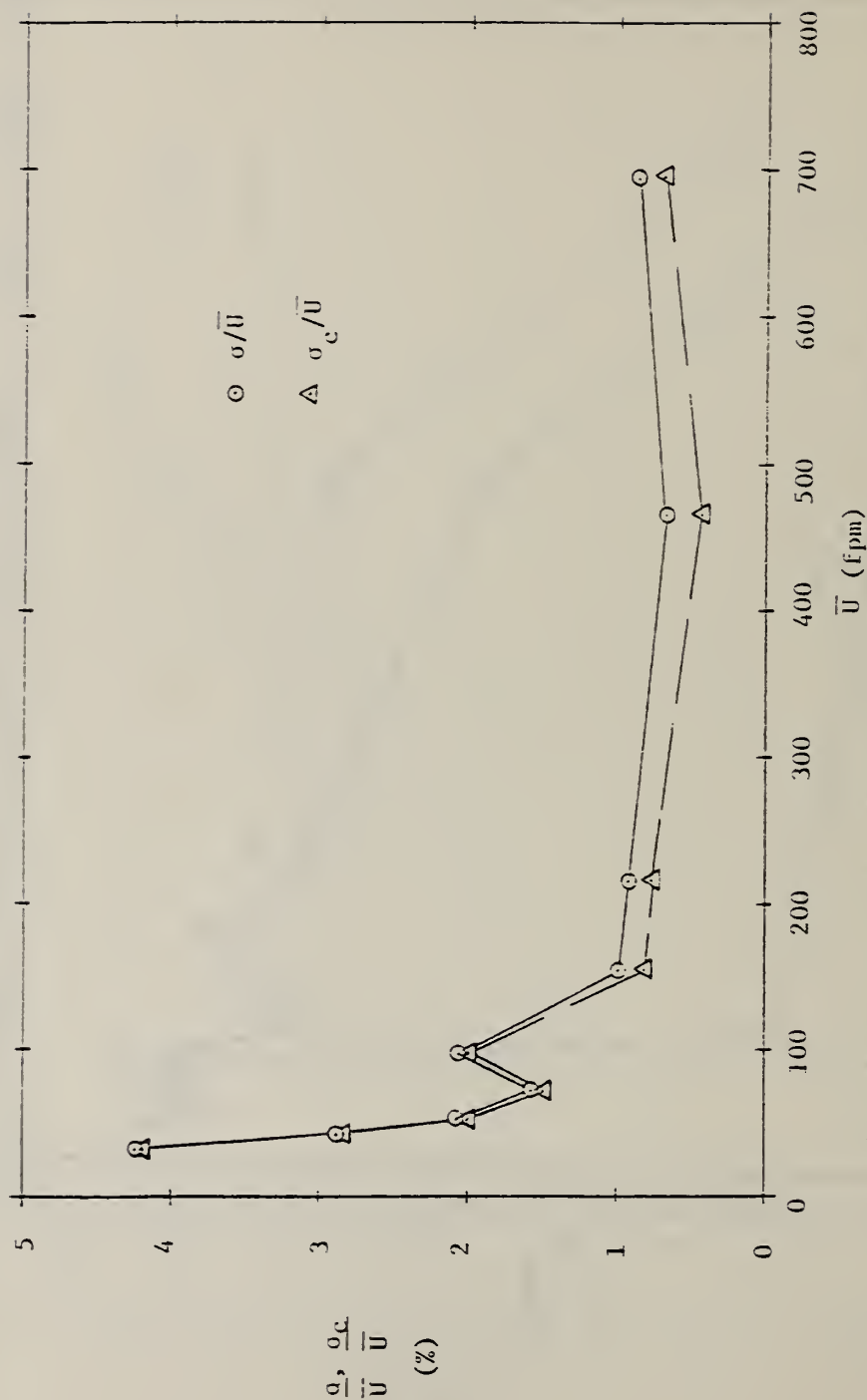


FIGURE 64. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , AS PERCENT OF GROUP MEAN VELOCITY. INSTRUMENT B.

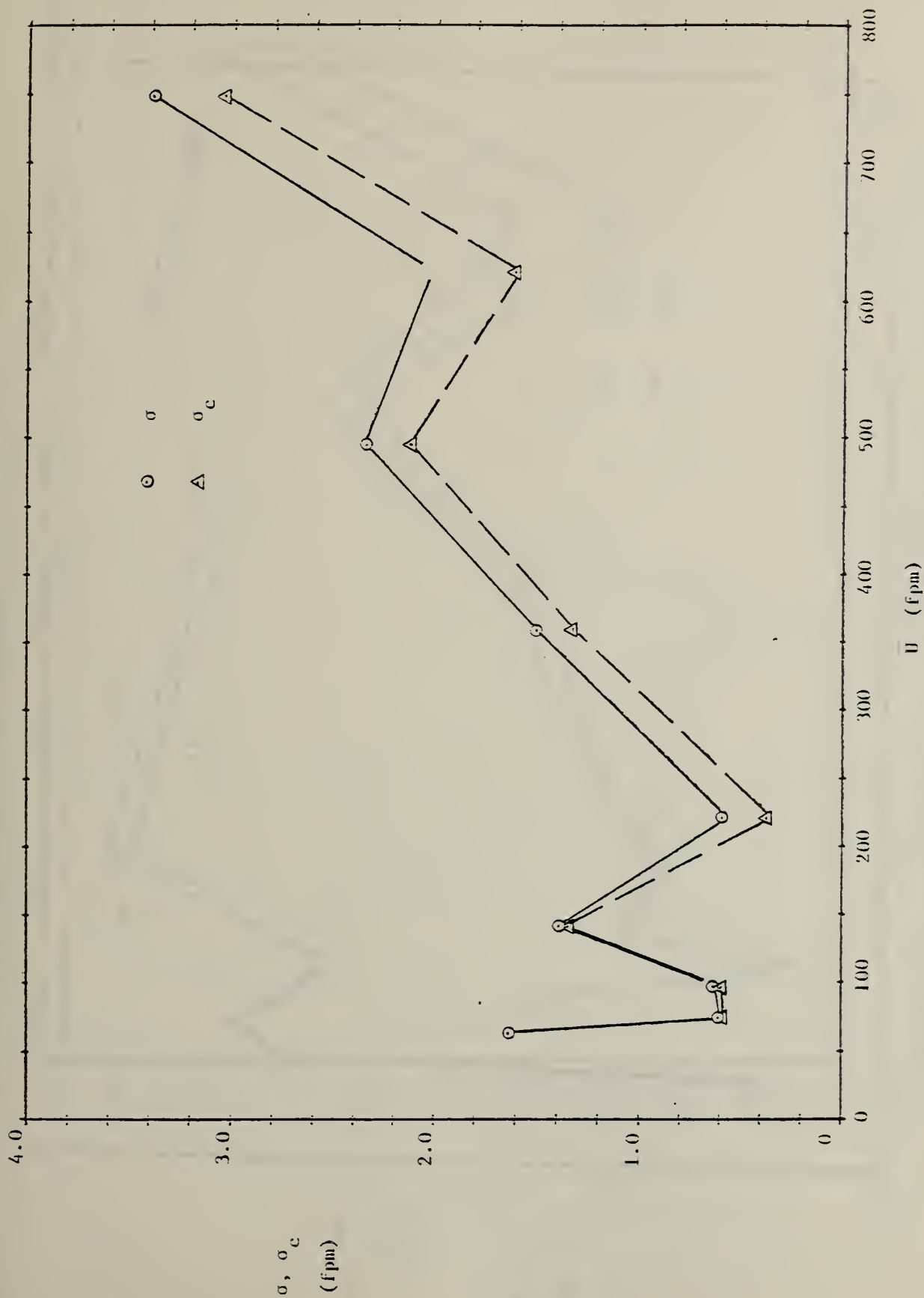


FIGURE 65. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ . INSTRUMENT C.

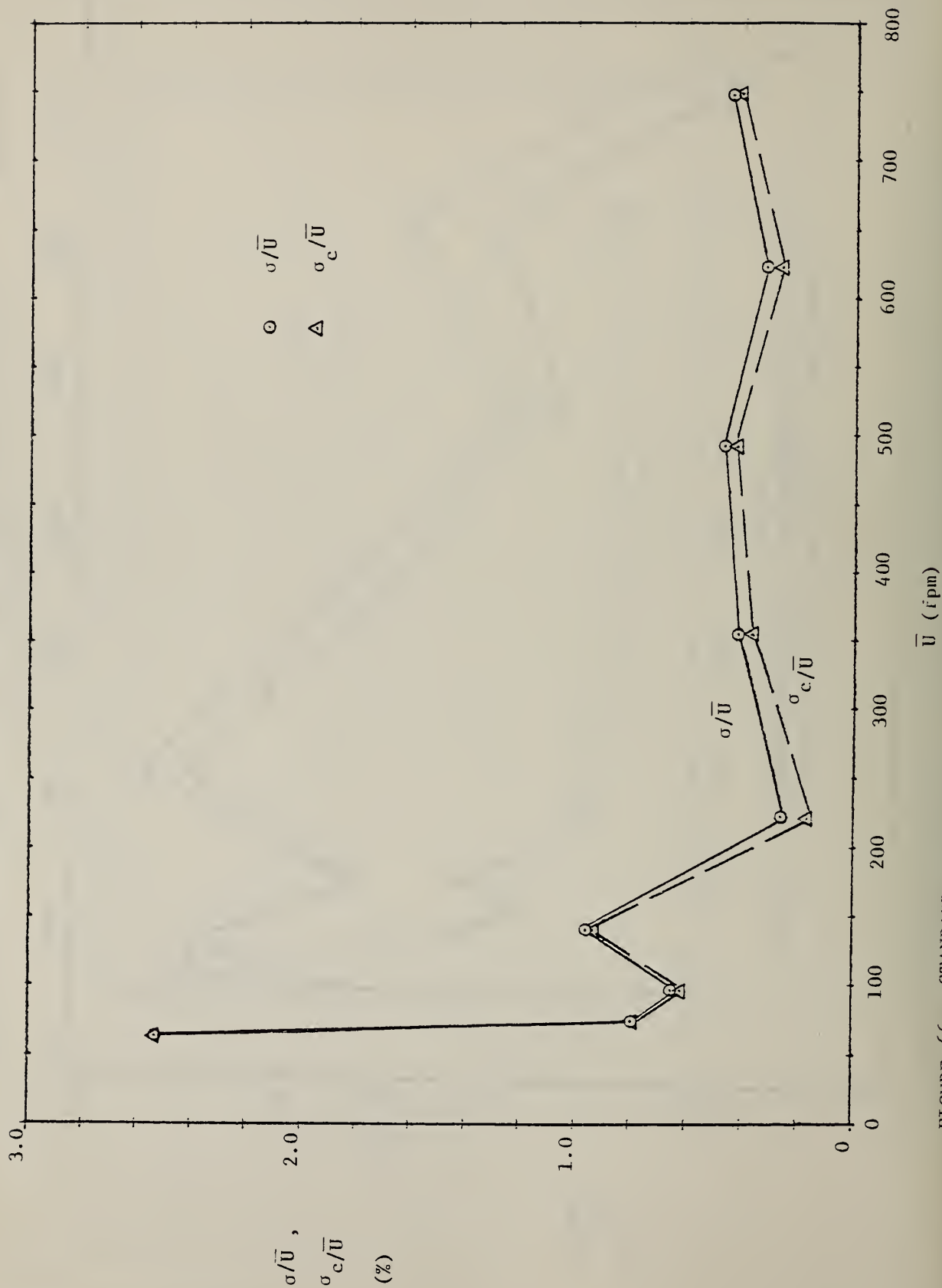


FIGURE 66. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , AS PERCENT OF GROUP MEAN VELOCITY. INSTRUMENT C.

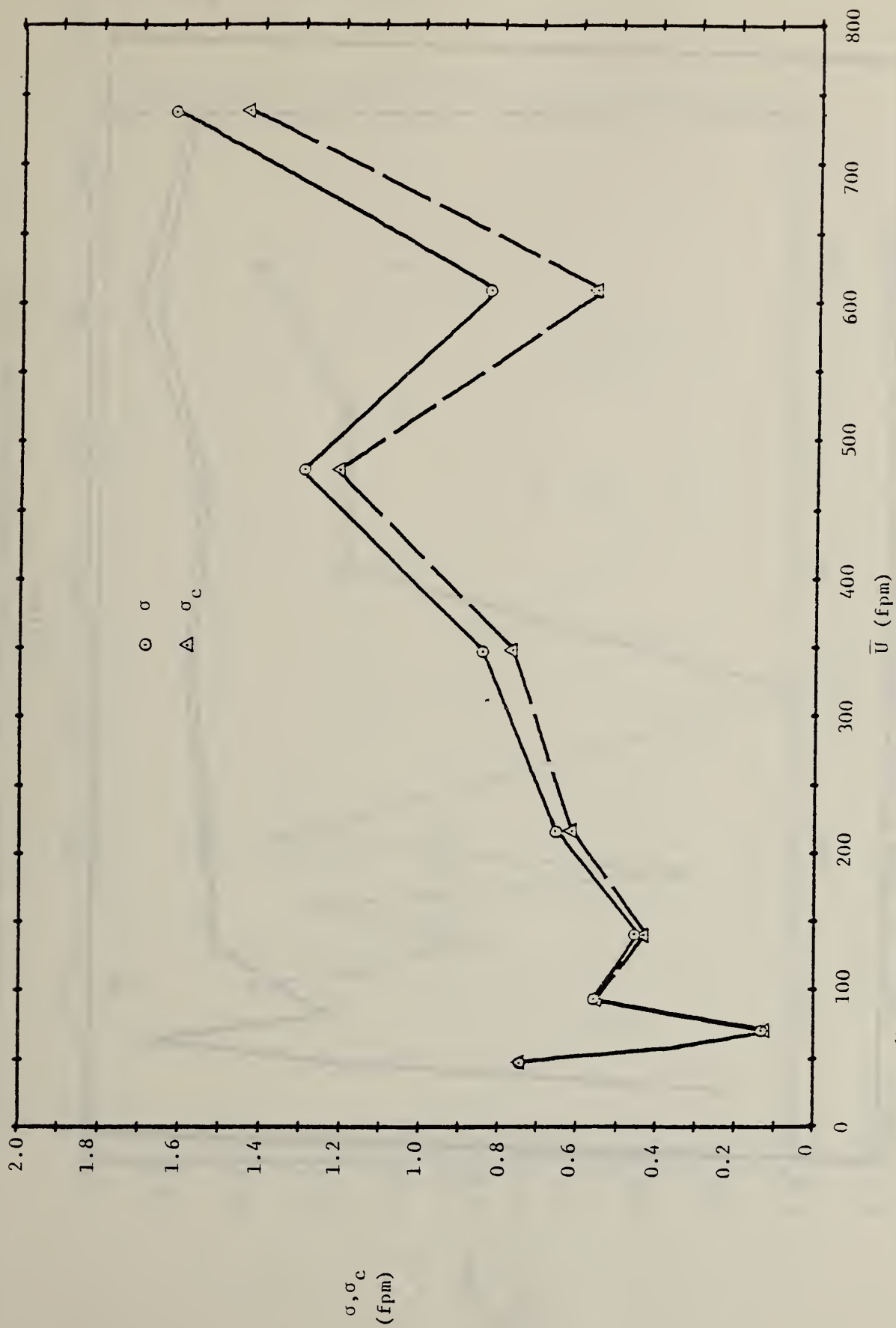


FIGURE 67. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , OF INDICATED VELOCITY IN TERMS OF TRUE VELOCITY. INSTRUMENT D.

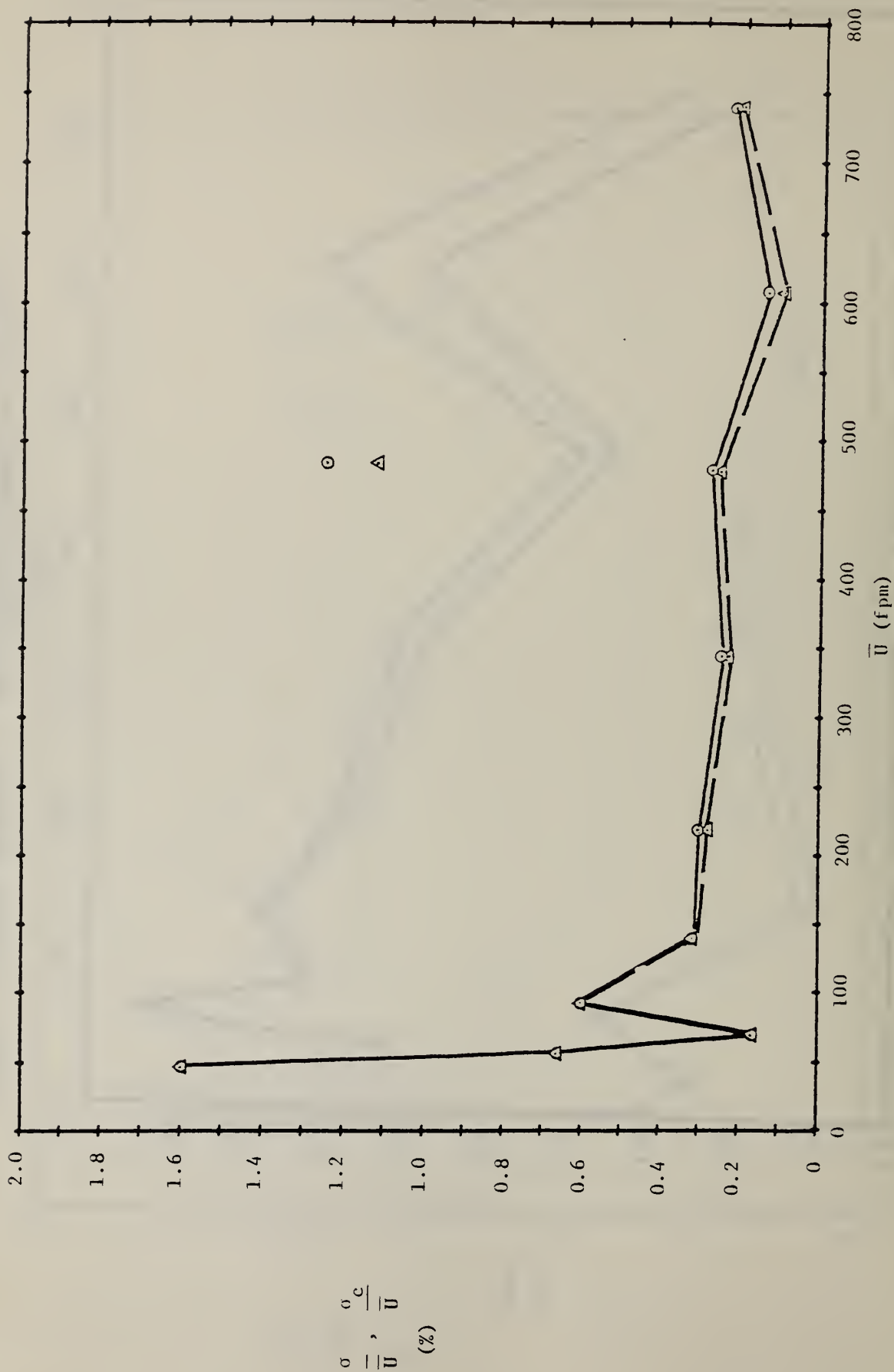


FIGURE 68. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , AS PERCENT OF GROUP MEAN VELOCITY. INSTRUMENT D.

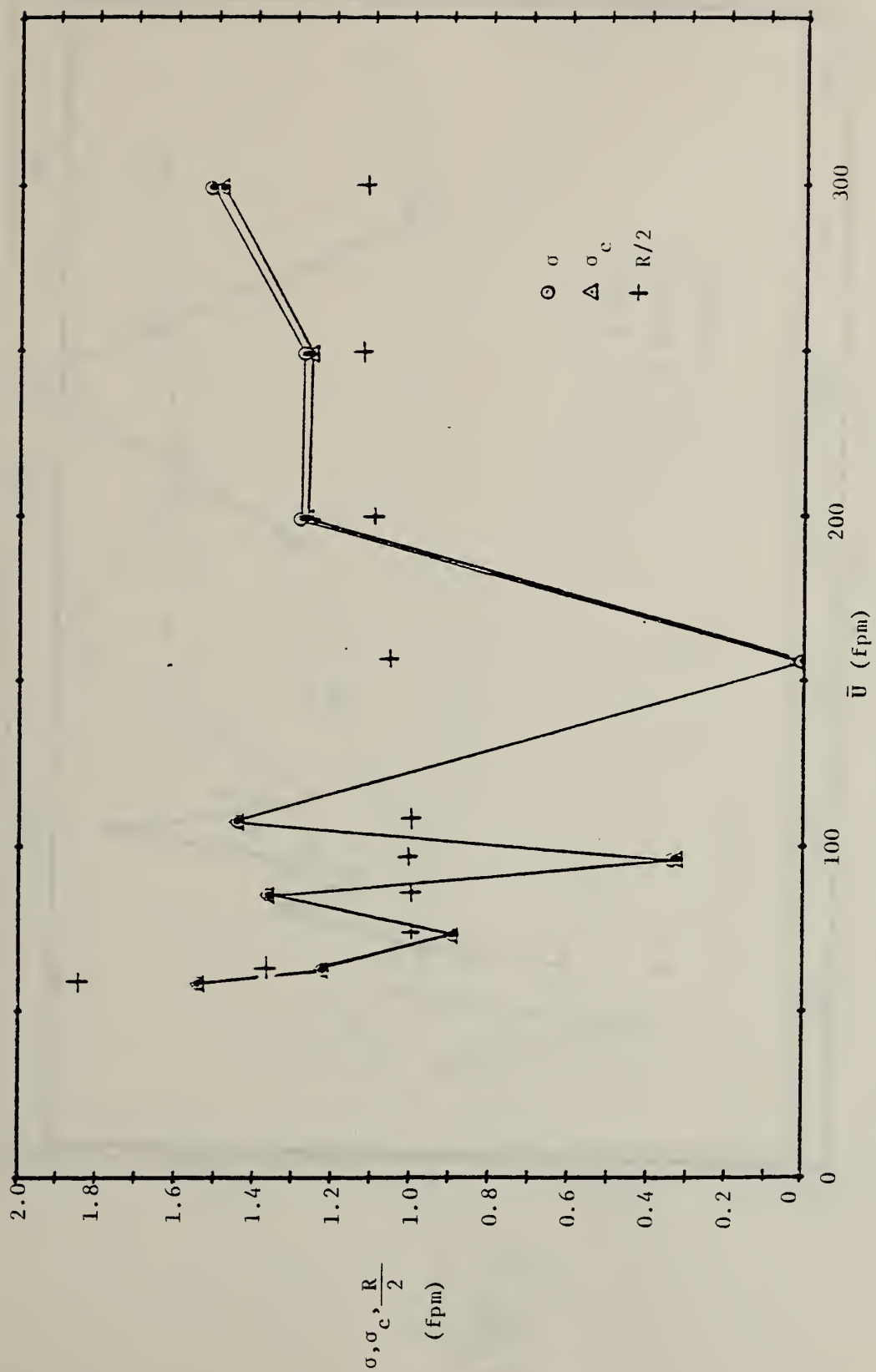


FIGURE 69.  $\sigma$  AND  $\sigma_c$  IN TERMS OF TRUE VELOCITY, LOW RANGE.  $R/2$  NOTED. INSTRUMENT E.

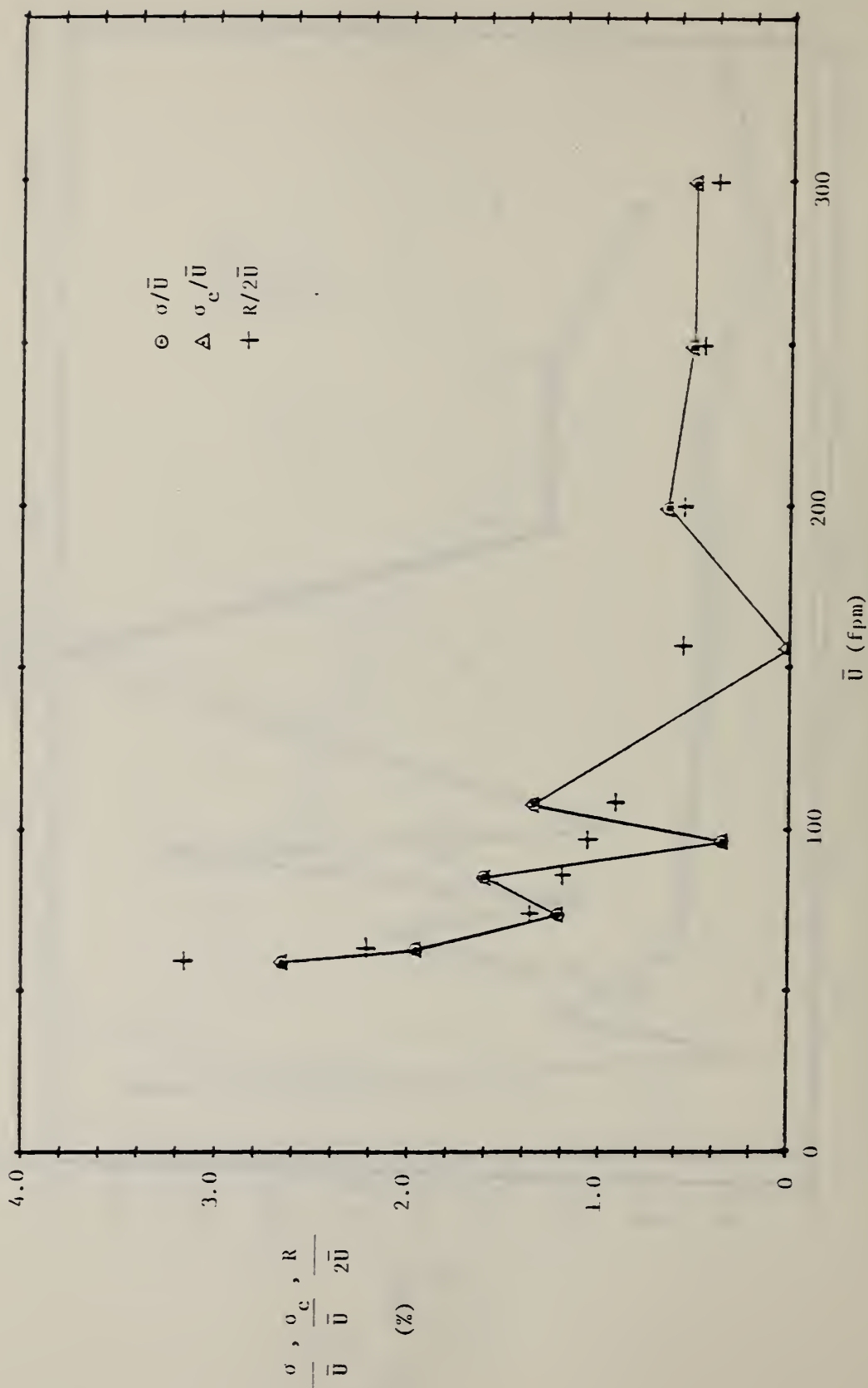


FIGURE 70.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY, LOW RANGE.  $R/2\bar{U}$  NOTED. INSTRUMENT E.

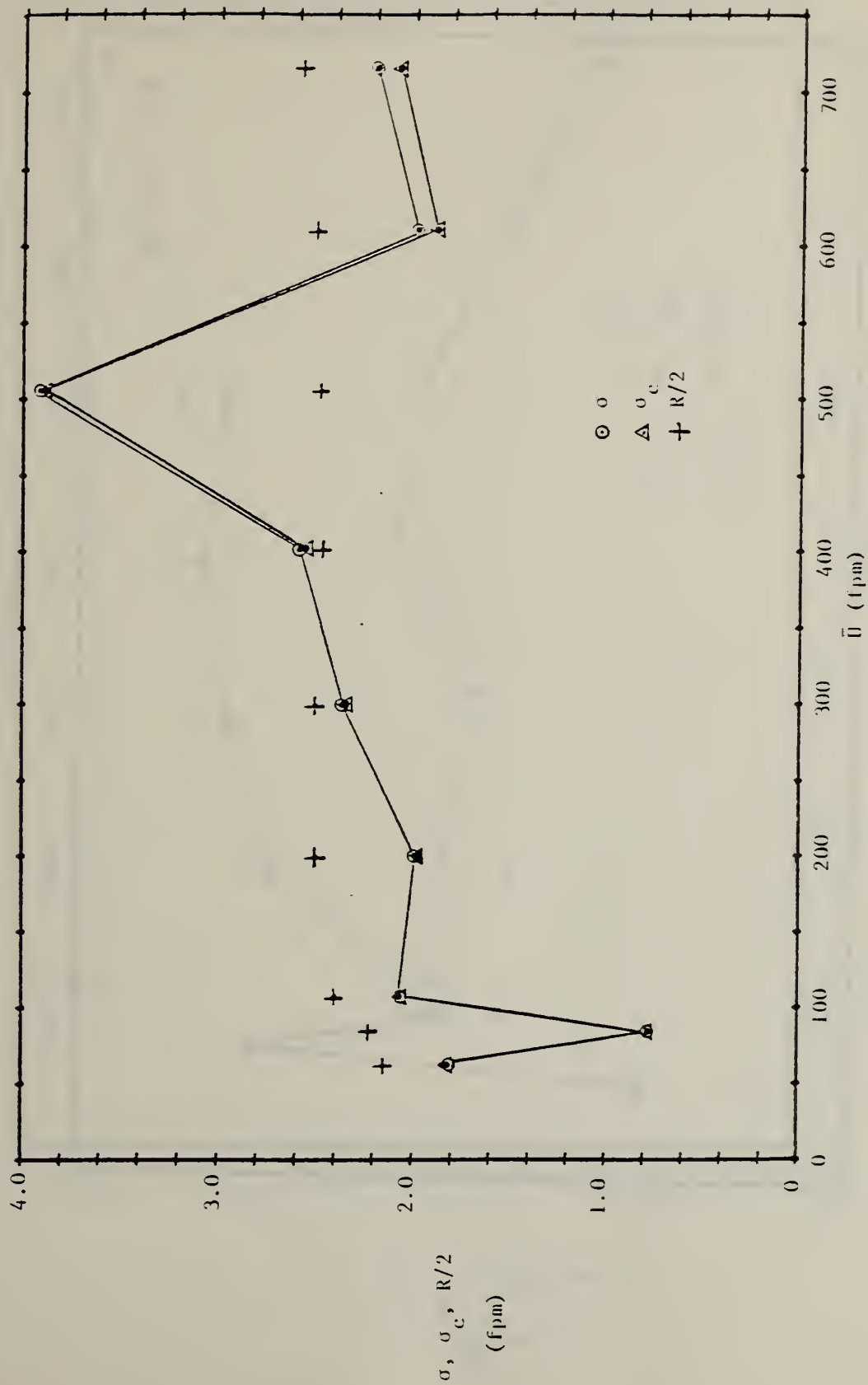


FIGURE 71.  $\sigma$  AND  $\sigma_c$  IN TERMS OF TRUE VELOCITY, MEDIUM RANGE.  $R/2$  NOTED. INSTRUMENT E.

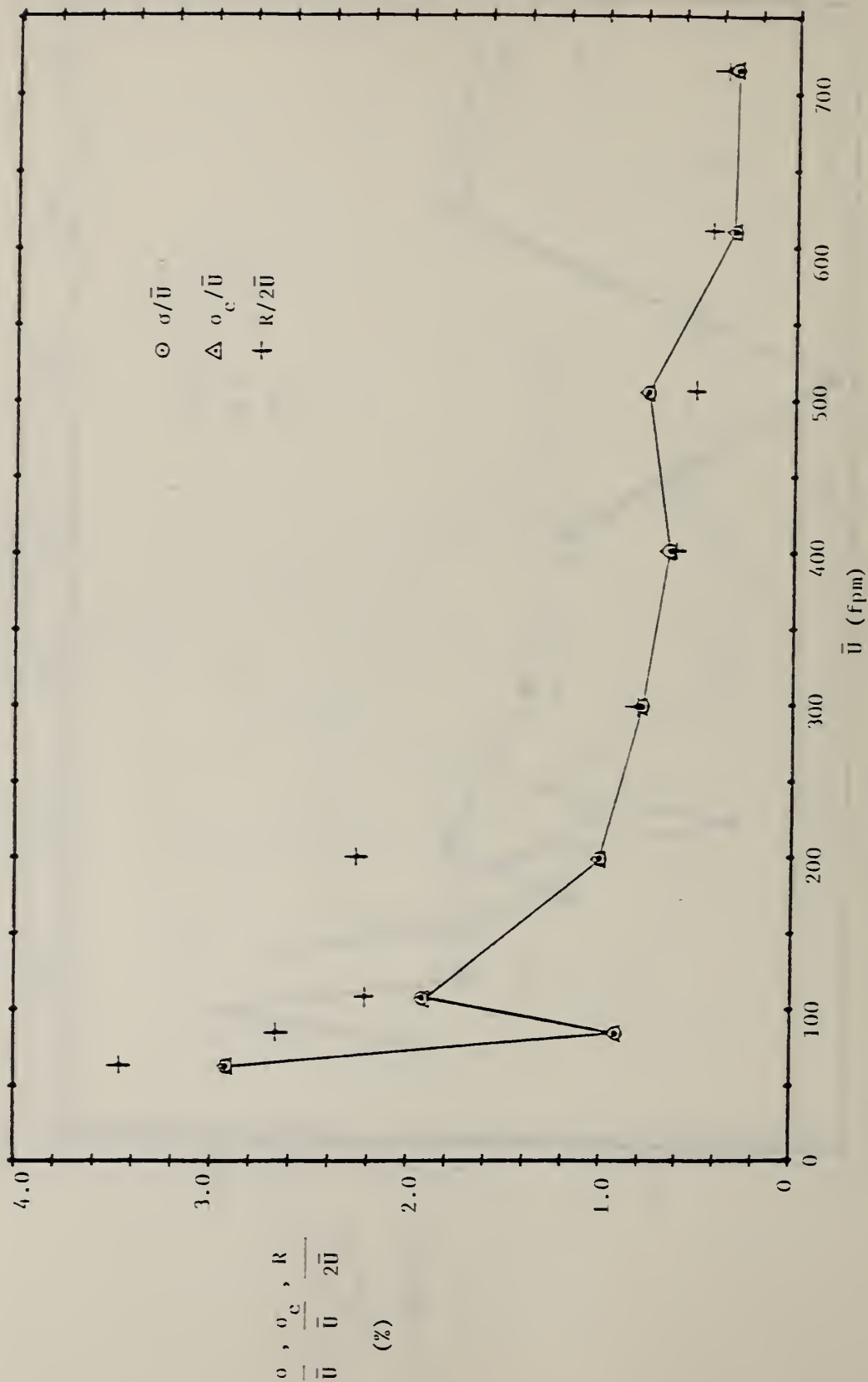


FIGURE 72.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY, MEDIUM RANGE.  $R/2\bar{U}$  NOTED.  
INSTRUMENT E.

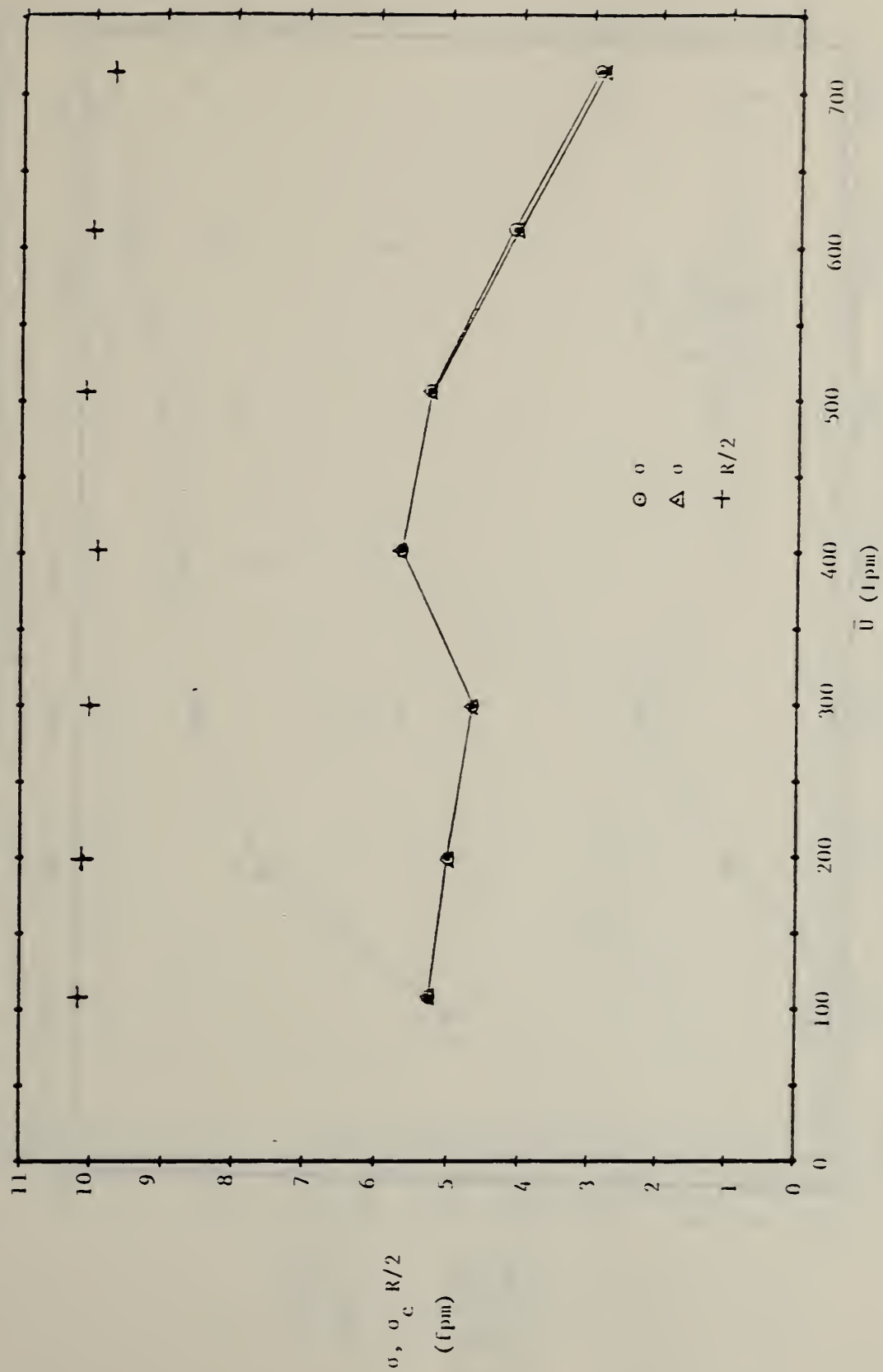


FIGURE 73.  $\sigma_c$  AND  $\sigma_c R/2$  IN TERMS OF TRUE VELOCITY, HIGH RANGE.  $R/2$  NOTED. INSTRUMENT E.

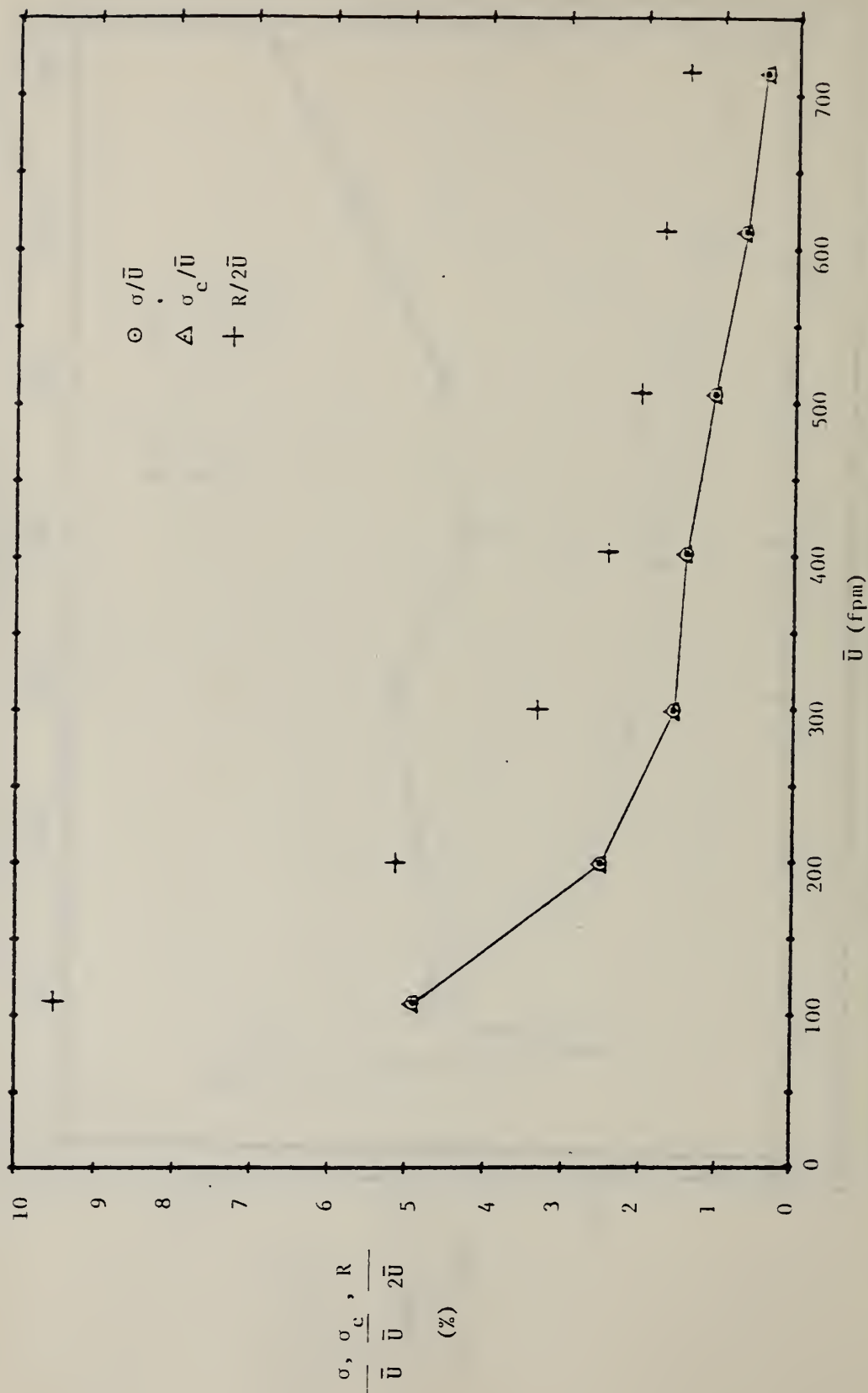


FIGURE 74.  $\sigma_c$  AND  $\sigma$  AS PERCENT OF GROUP MEAN VELOCITY, HIGH RANGE.  $R/2\bar{U}$  NOTED. INSTRUMENT E.

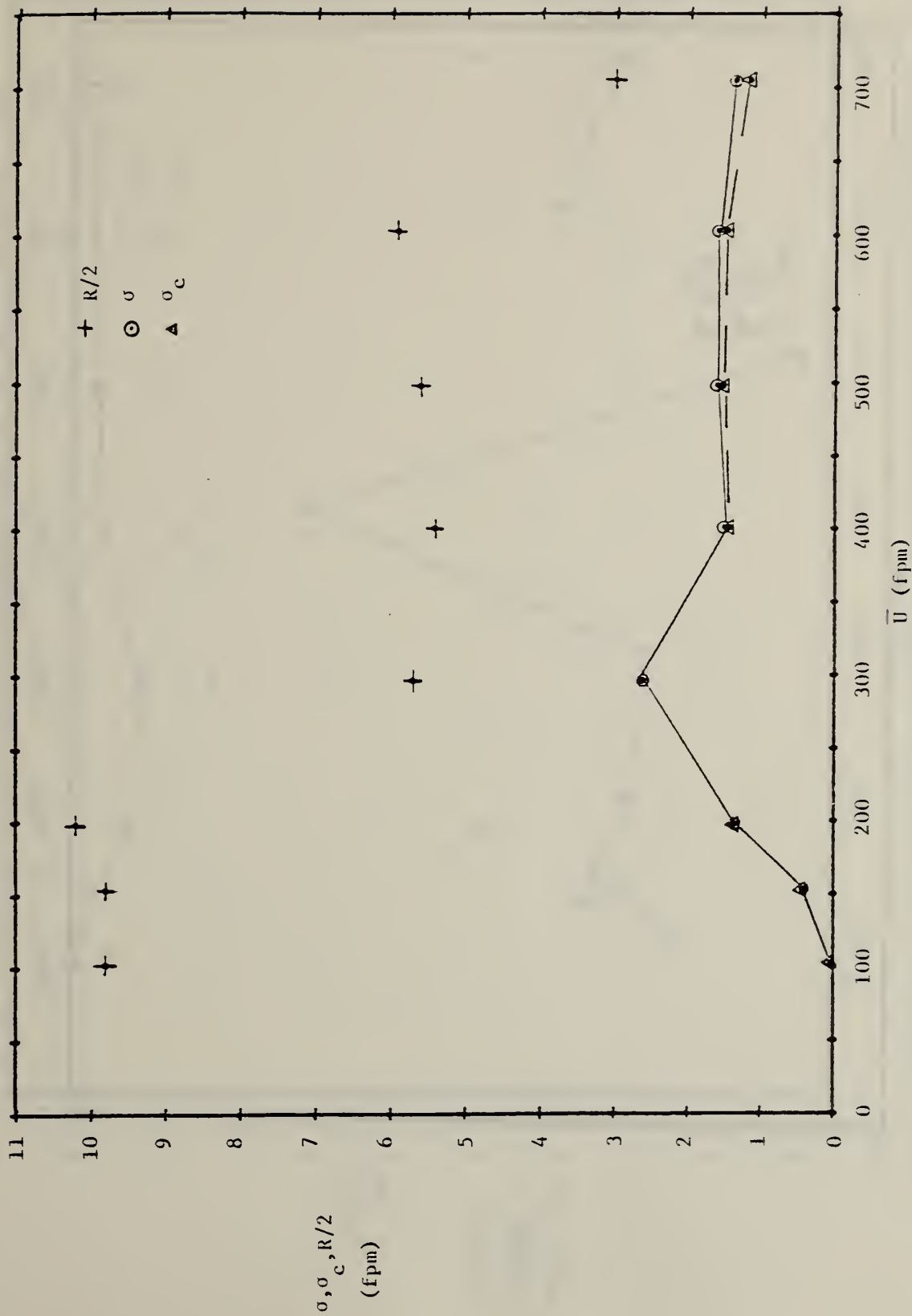


FIGURE 75.  $\sigma$  AND  $\sigma_c$  IN TERMS OF TRUE VELOCITY FOR PITOT PROBE, LOW RANGE.  $R/2$  NOTED. INSTRUMENT F.

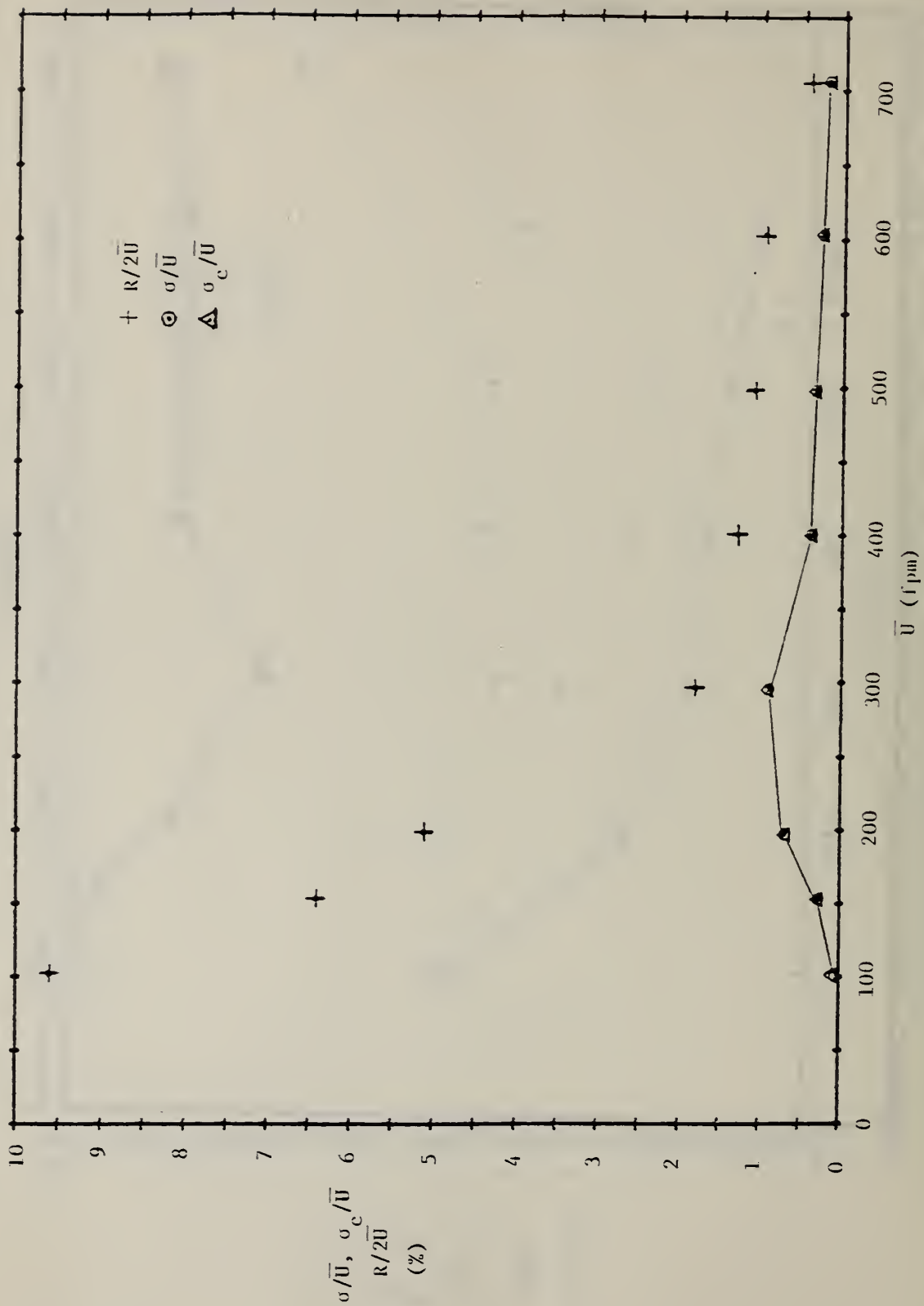


FIGURE 76.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY FOR PITOT PROBE, LOW RANGE.  $R/2 \bar{U}$  NOTED.  $\sigma_c$  INSTRUMENT F.

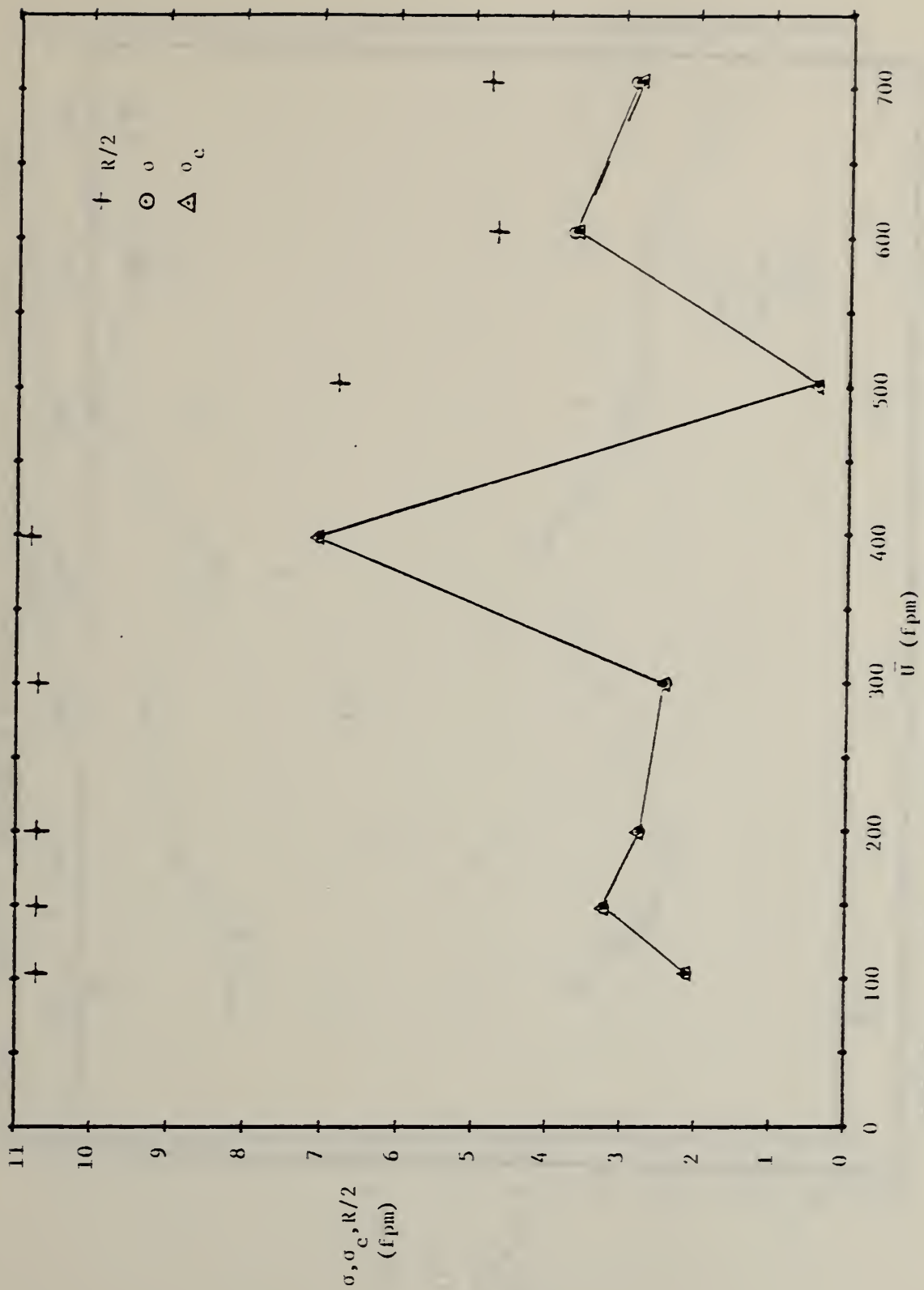


FIGURE 77.  $\sigma$  and  $\sigma_c$  IN TERMS OF TRUE VELOCITY FOR PITOT PROBE, HIGH RANGE.  $R/2$  NOTED. INSTRUMENT F.

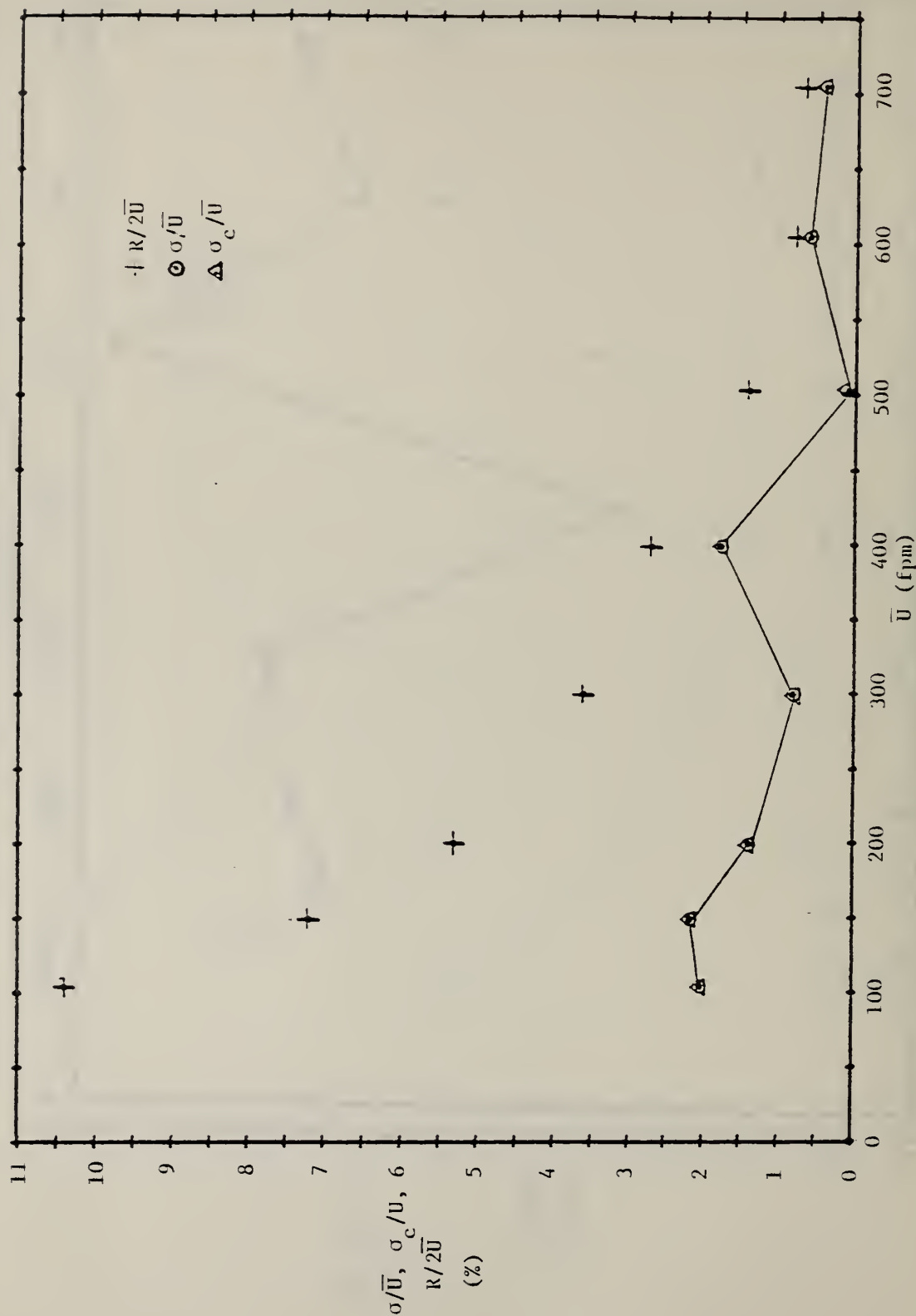


FIGURE 78.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY FOR PITOT PROBE, HIGH RANGE.  
 $R/2\bar{U}$  NOTED. INSTRUMENT F.

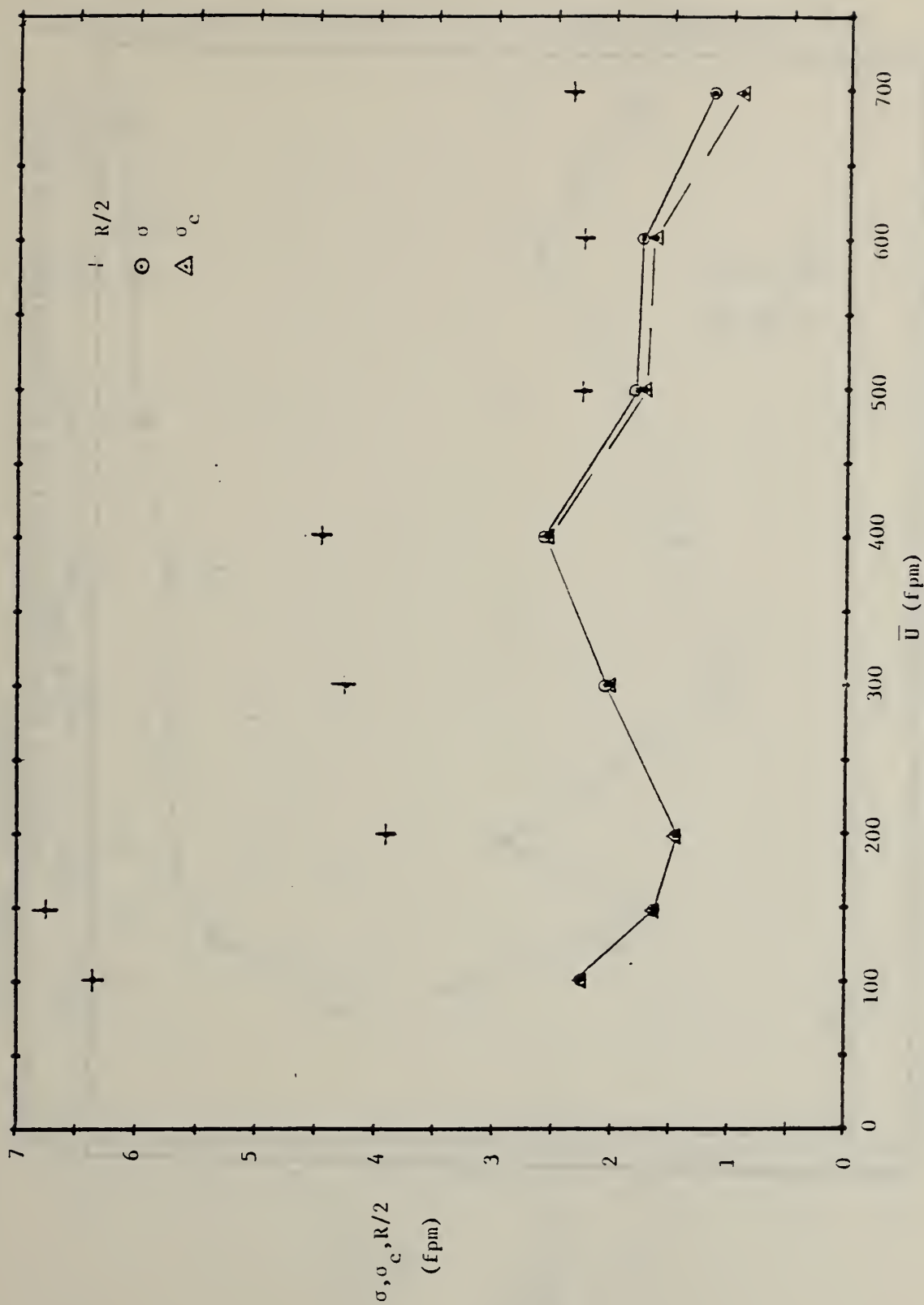


FIGURE 79.  $\sigma$  AND  $\sigma_c$  IN TERMS OF TRUE VELOCITY FOR DIFFUSER PROBE, LOW RANGE.  $R/2$  NOTED. INSTRUMENT F.

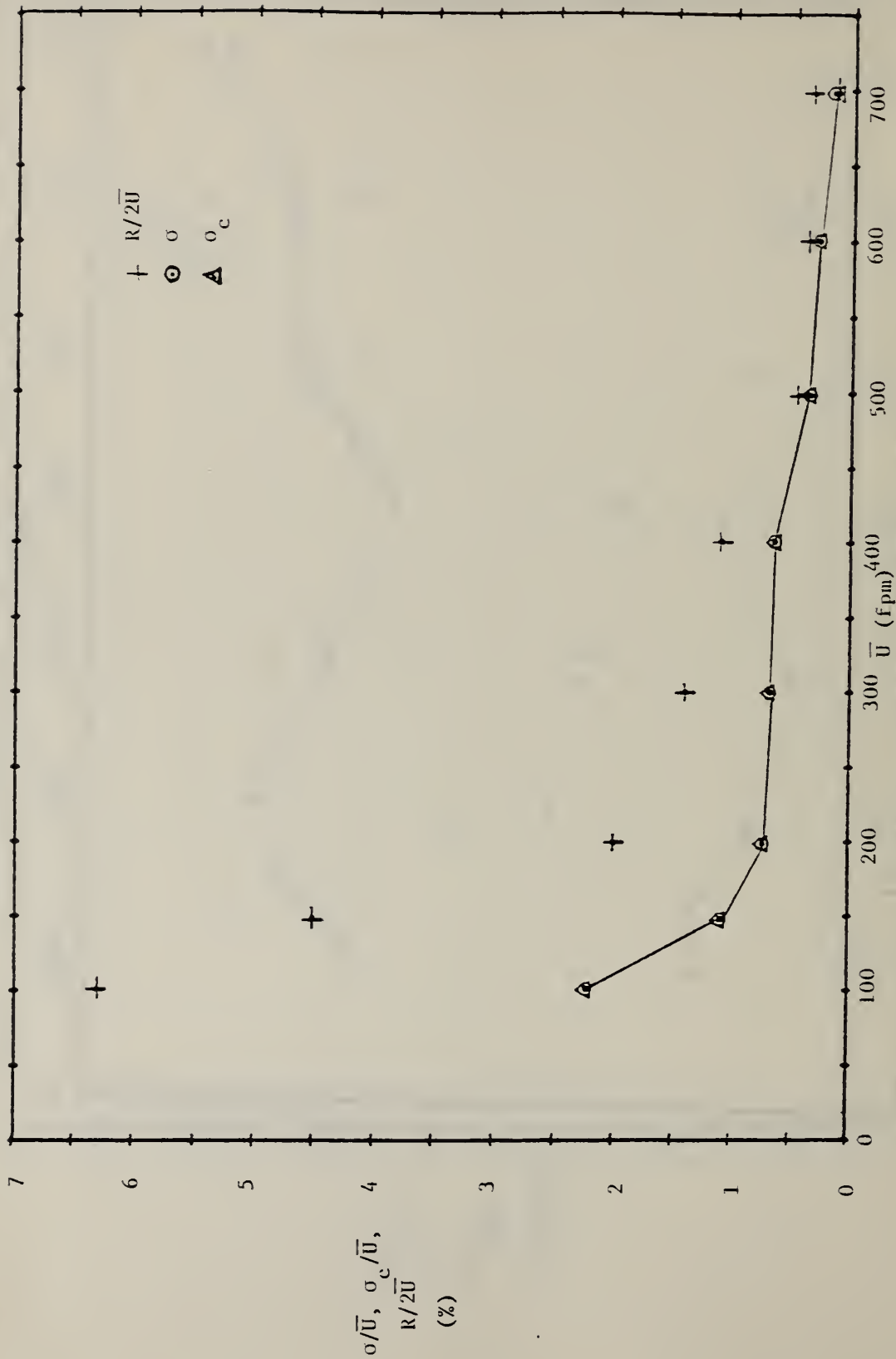


FIGURE 80.  $\sigma$  and  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY FOR DIFFUSER PROBE, LOW RANGE.  
R/2U NOTED. INSTRUMENT P.

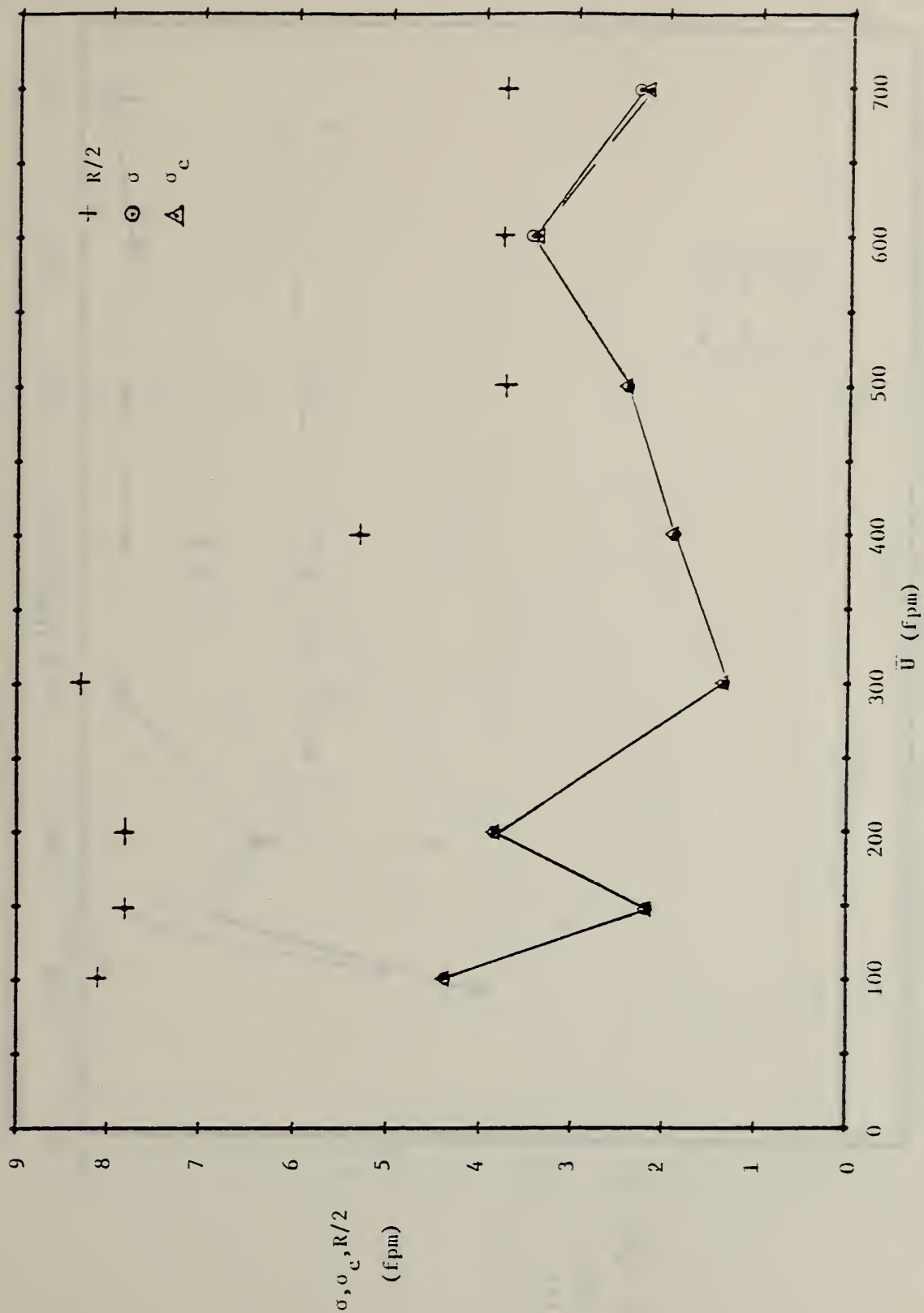


FIGURE 81.  $\sigma$  AND  $\sigma_c$  IN TERMS OF TRUE VELOCITY FOR DIFFUSER PROBE, HIGH RANGE.  $R/2$  NOTED. INSTRUMENT P.

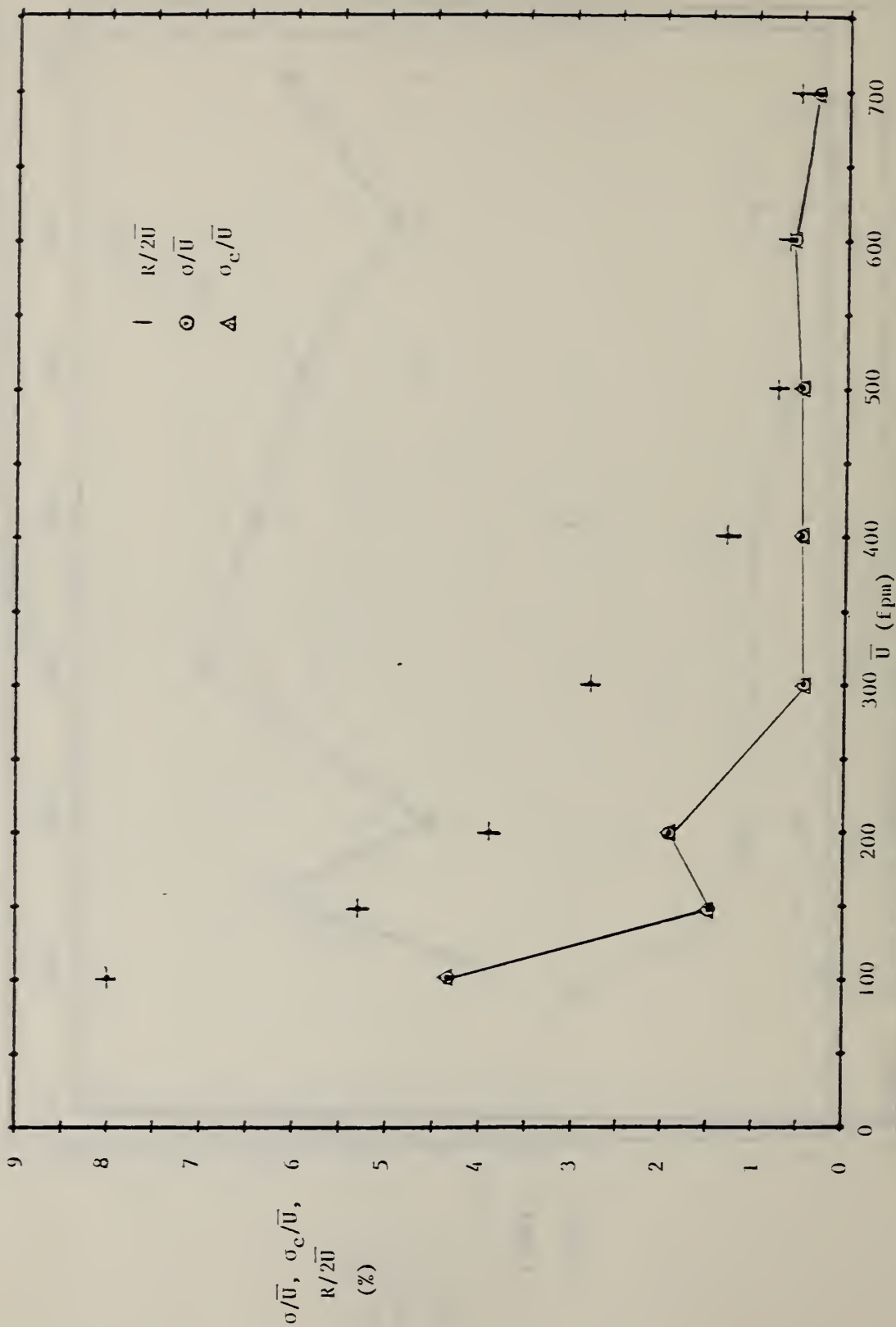


FIGURE 82.  $\sigma$  and  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY FOR DIFFUSER PROBE, HIGH RANGE.  
 $R/2U$  NOTED. INSTRUMENT F.

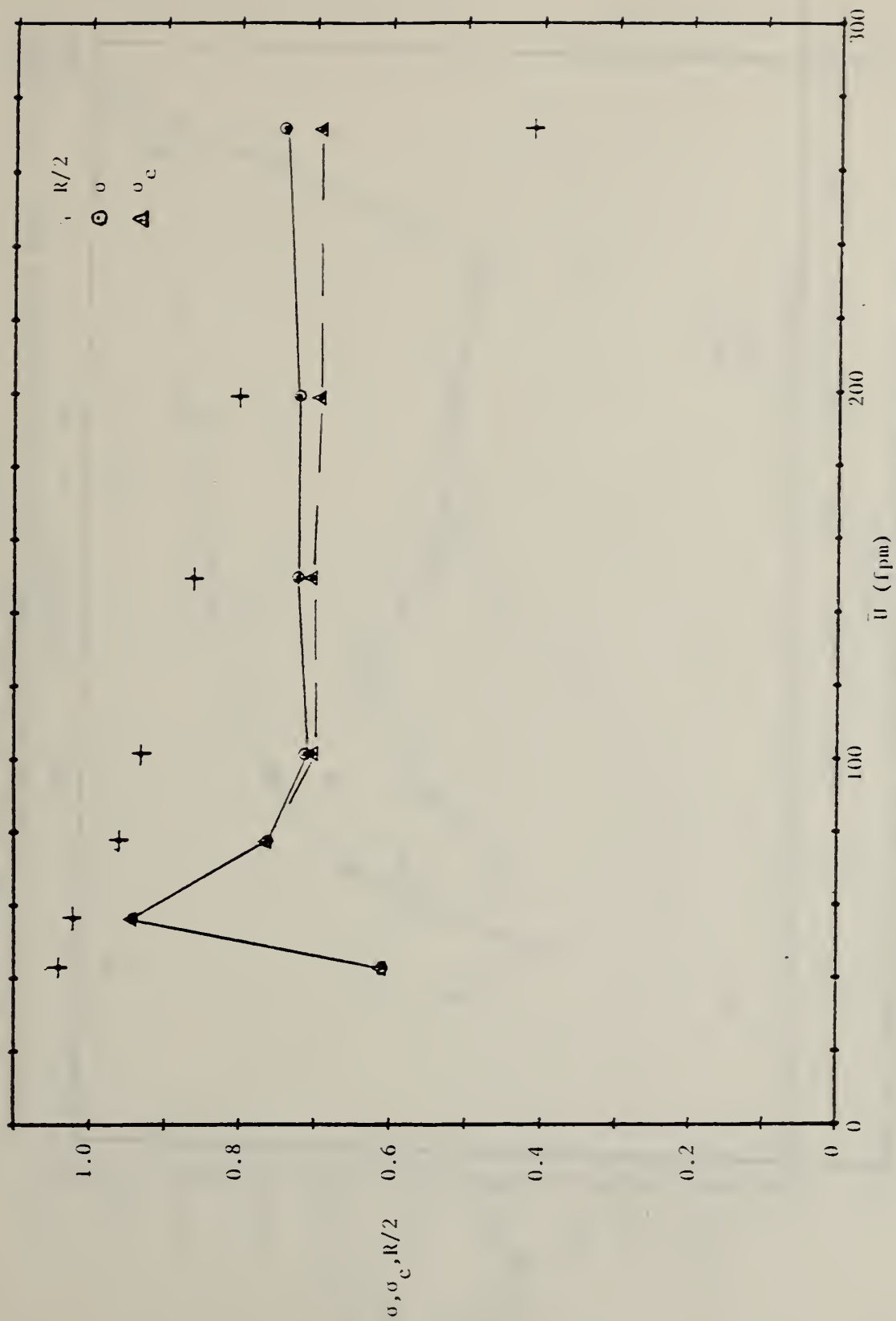


FIGURE 83.  $\sigma$  AND  $\sigma_c$  IN TERMS OF TRUE VELOCITY FOR LOW VELOCITY PROBE.  $R/2$  NOTED.  
INSTRUMENT F.

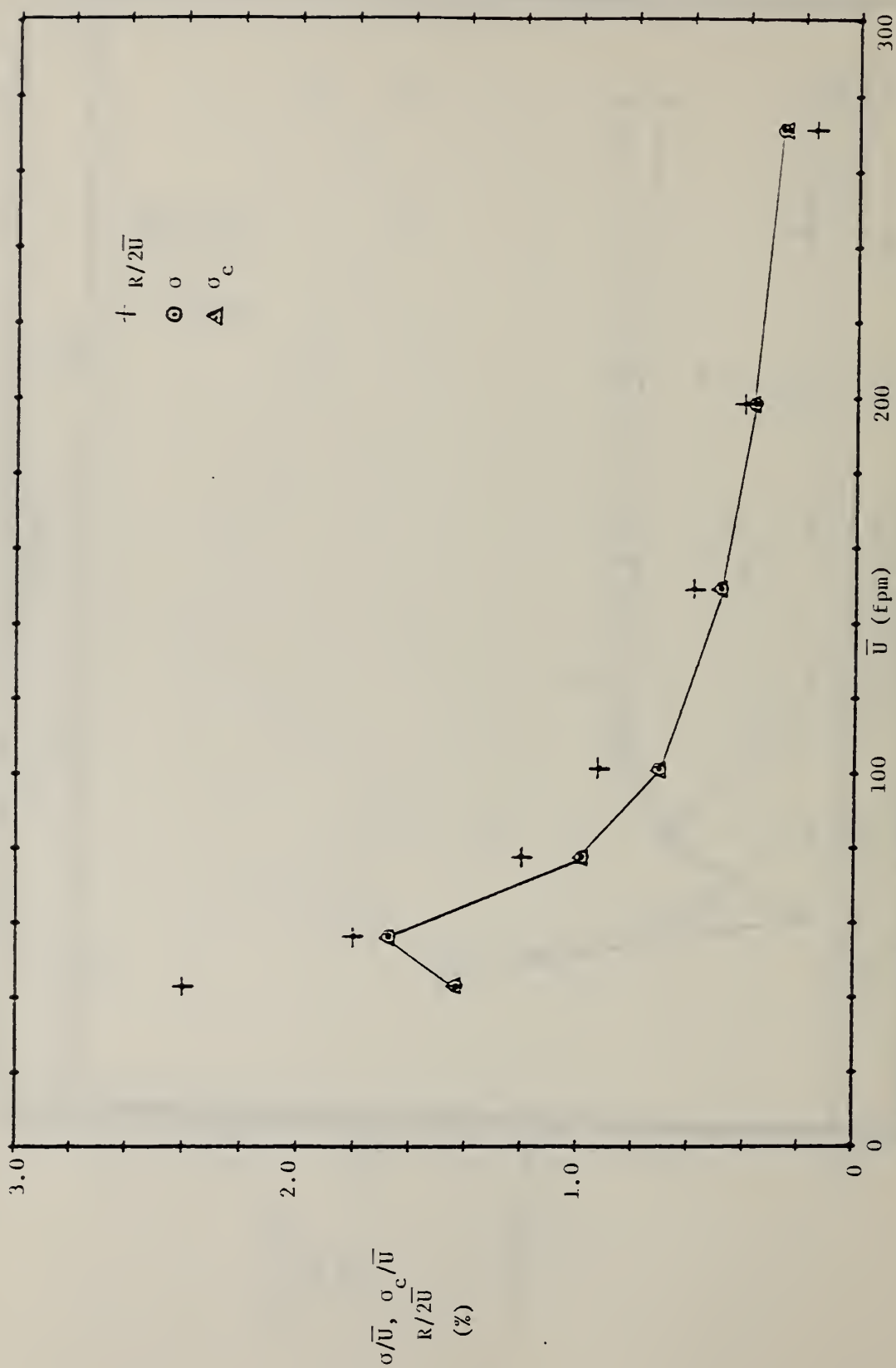


FIGURE 84.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY FOR LOW VELOCITY PROBE.  $R/2\bar{U}$  NOTED. INSTRUMENT F.

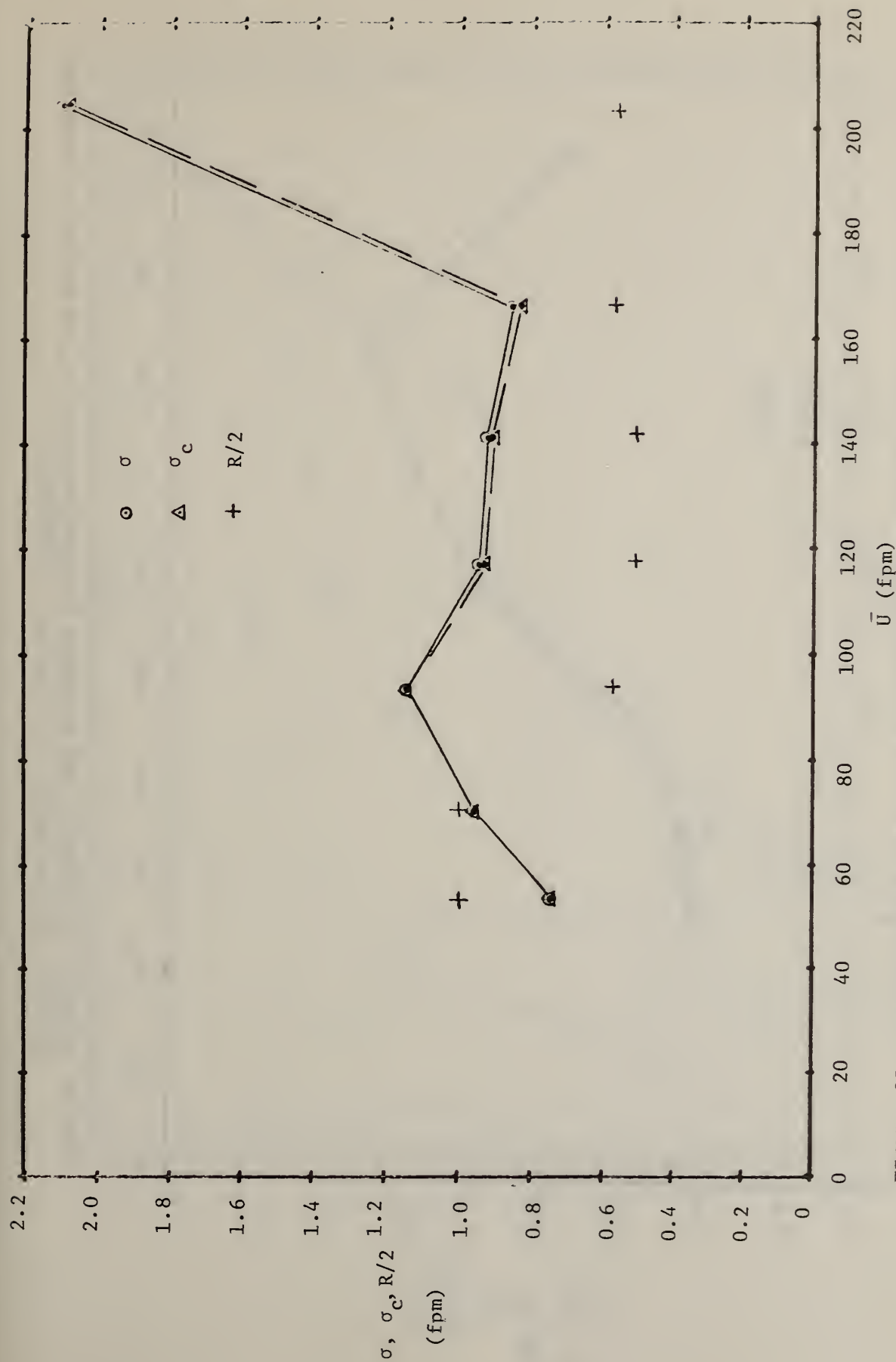


FIGURE 85. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , OF INDICATED VELOCITY IN TERMS OF TRUE VELOCITY, LOW RANGE.  $R/2$  NOTED. INSTRUMENT C.

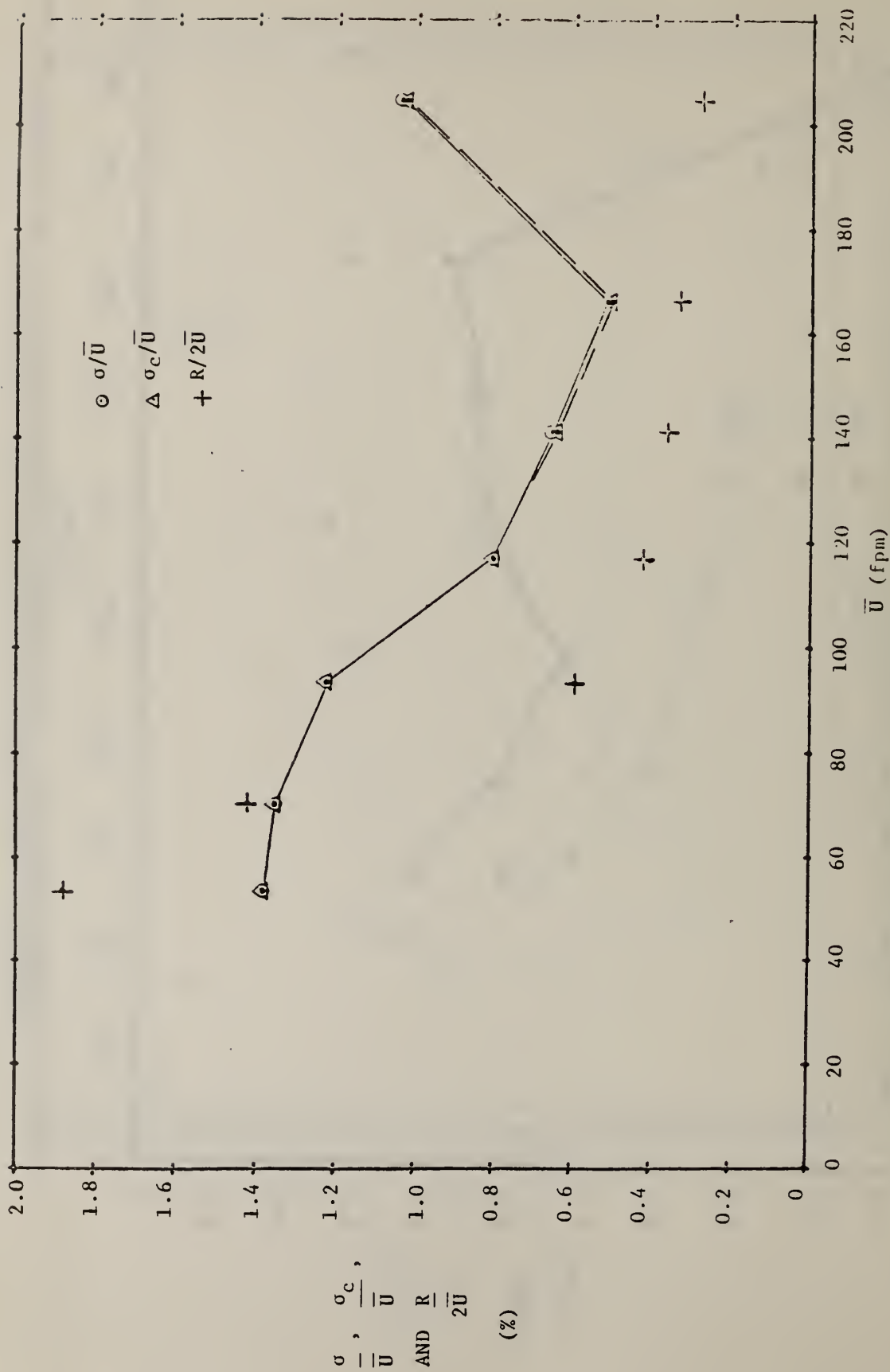


FIGURE 86. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , AS PERCENT OF GROUP MEAN VELOCITY, FOR LOW RANGE.  $R/2\bar{U}$  NOTED. INSTRUMENT G.

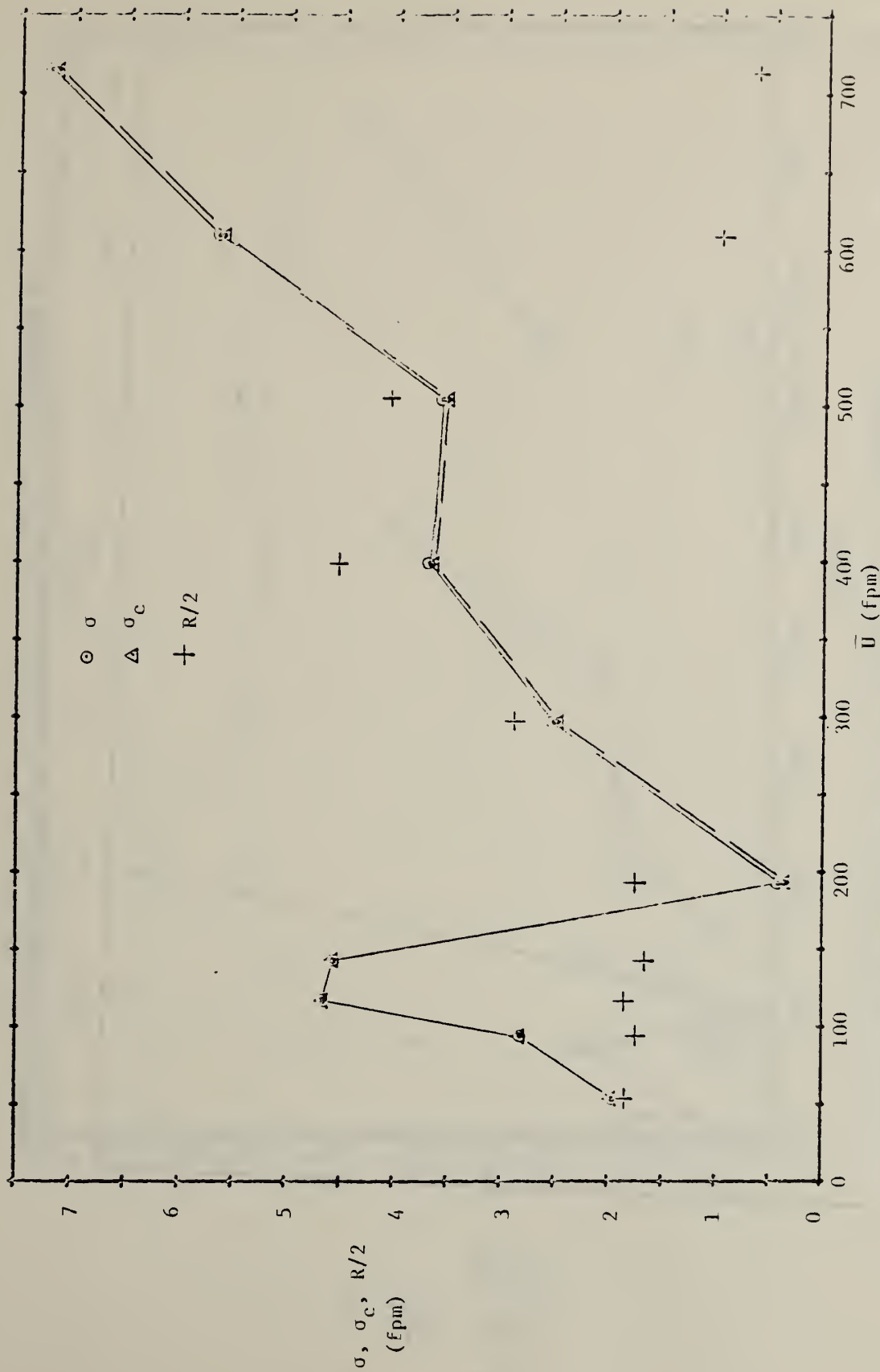


FIGURE 87. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , OF INDICATED VELOCITY IN TERMS OF TRUE VELOCITY, HIGH RANGE.  $R/2$  NOTED. INSTRUMENT G.

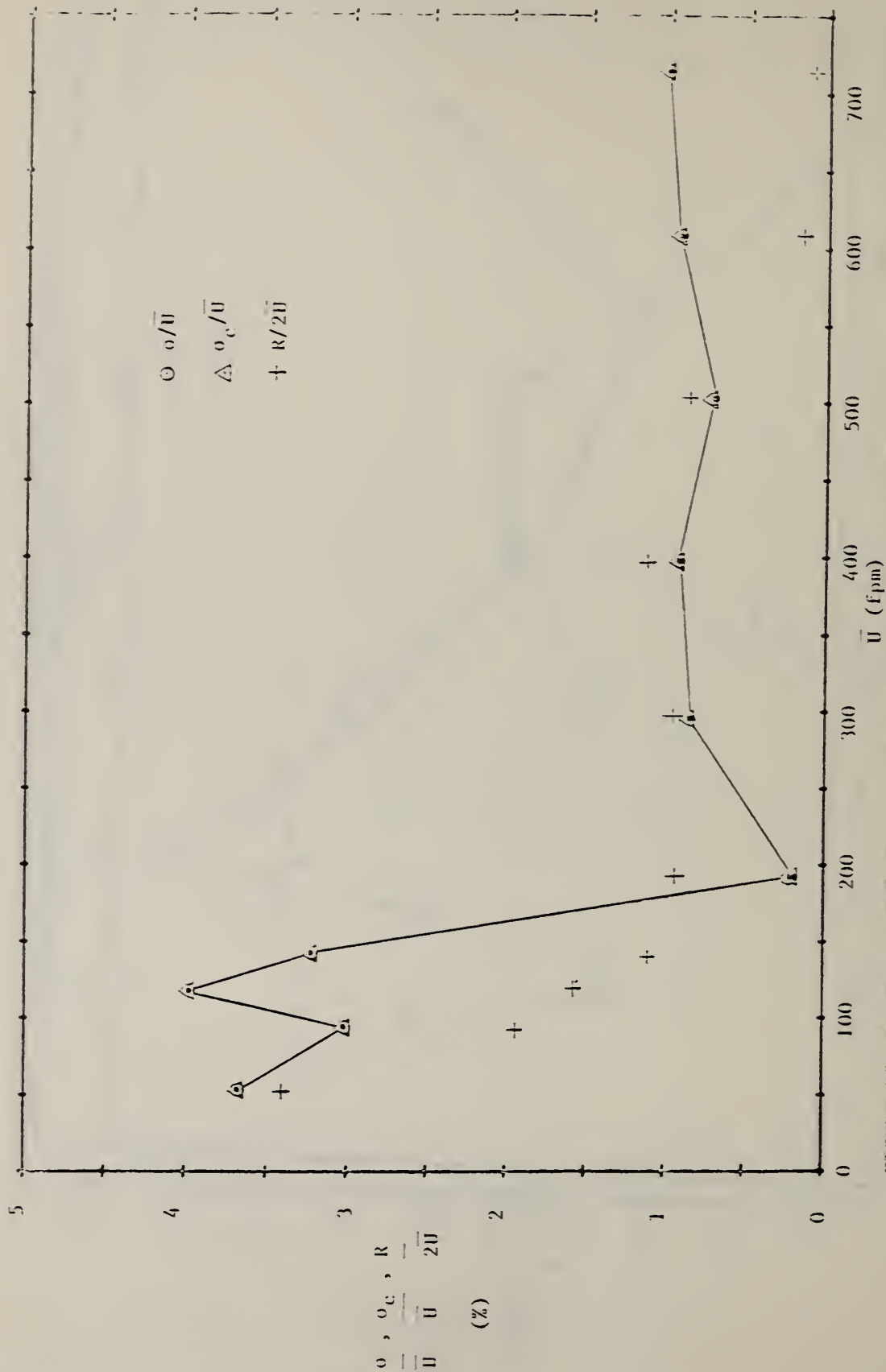


FIGURE 88. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , AS PERCENT OF GROUP MEAN VELOCITY,  $\bar{u}$ , FOR HIGH RANGE.  $R/2\bar{u}$  NOTED. INSTRUMENT G.

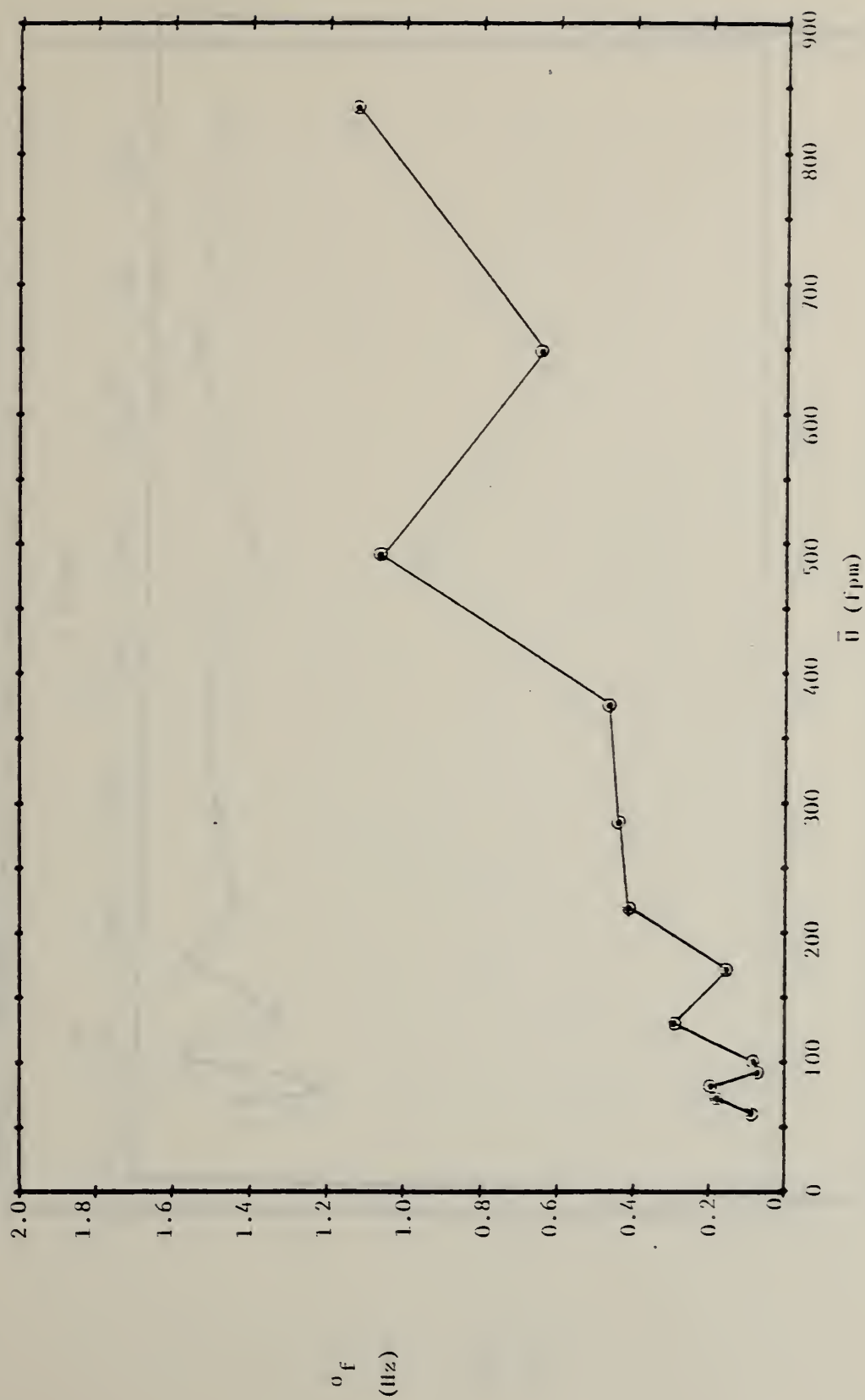


FIGURE 89. STANDARD DEVIATION OF PULSE FREQUENCY. INSTRUMENT II.

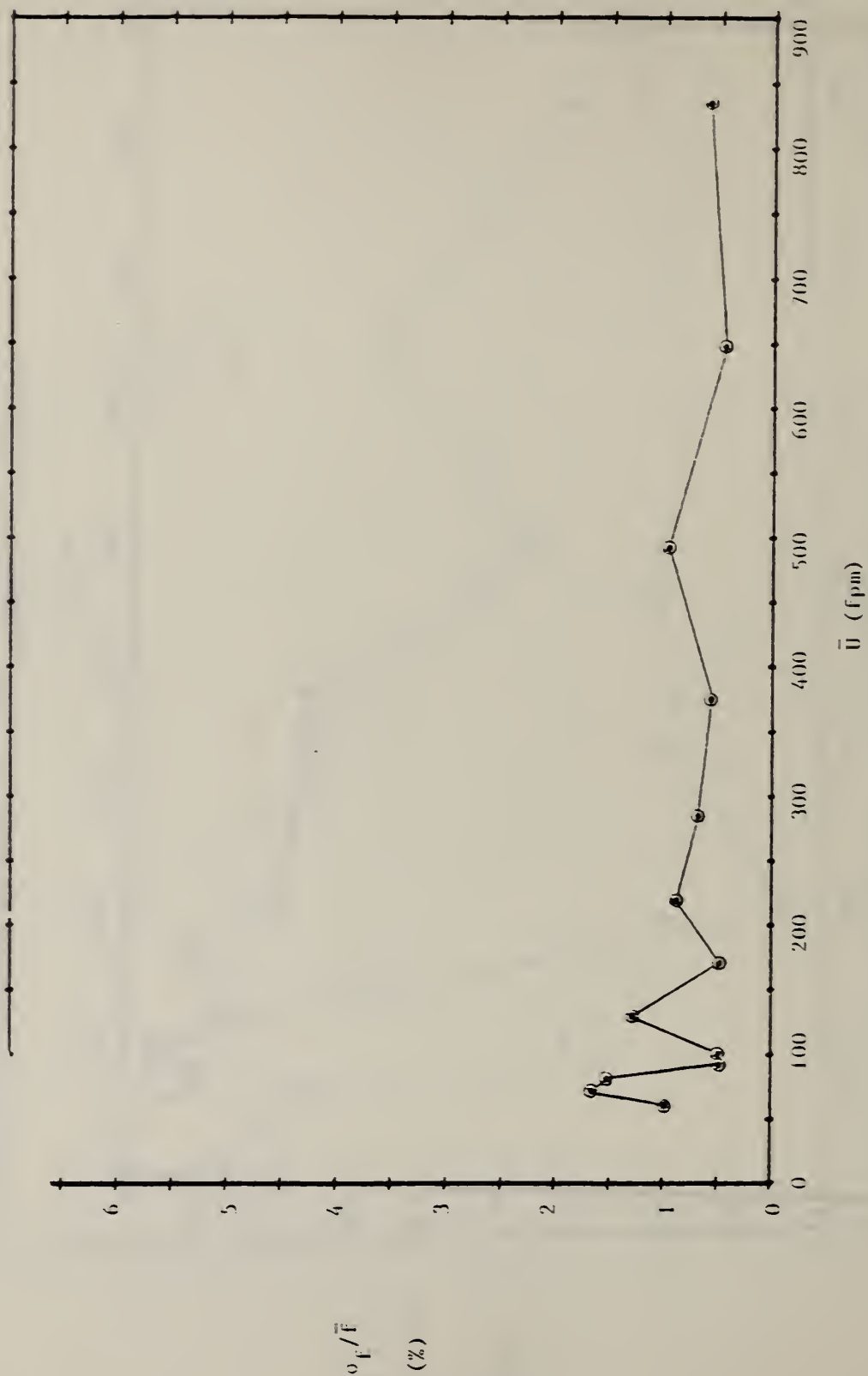


FIGURE 90. STANDARD DEVIATION OF PULSE FREQUENCY AS PERCENT OF GROUP MEAN FREQUENCY.  
INSTRUMENT II.

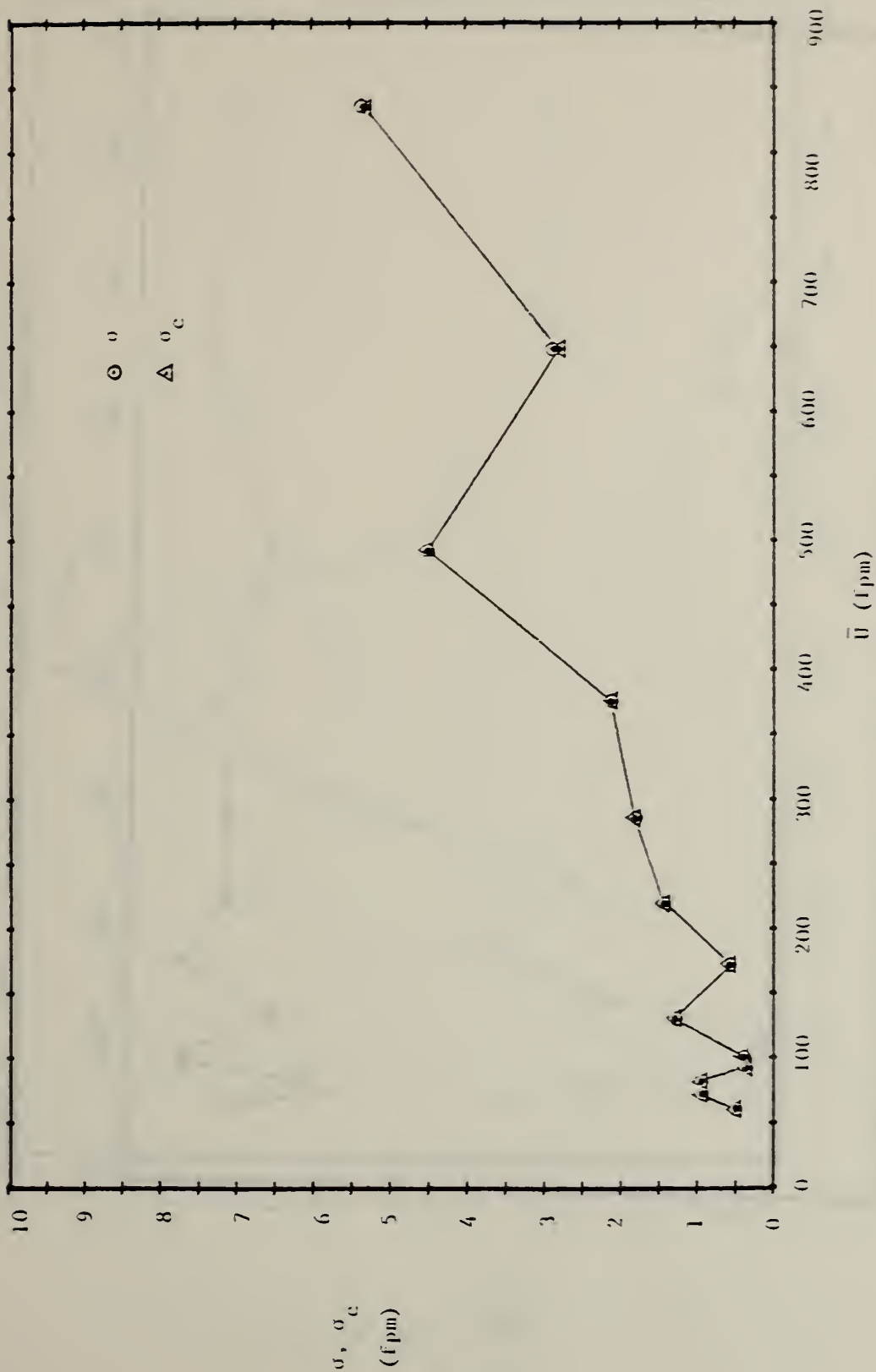


FIGURE 91. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , EXPRESSED AS EQUIVALENT TRUE VELOCITY. INSTRUMENT II.

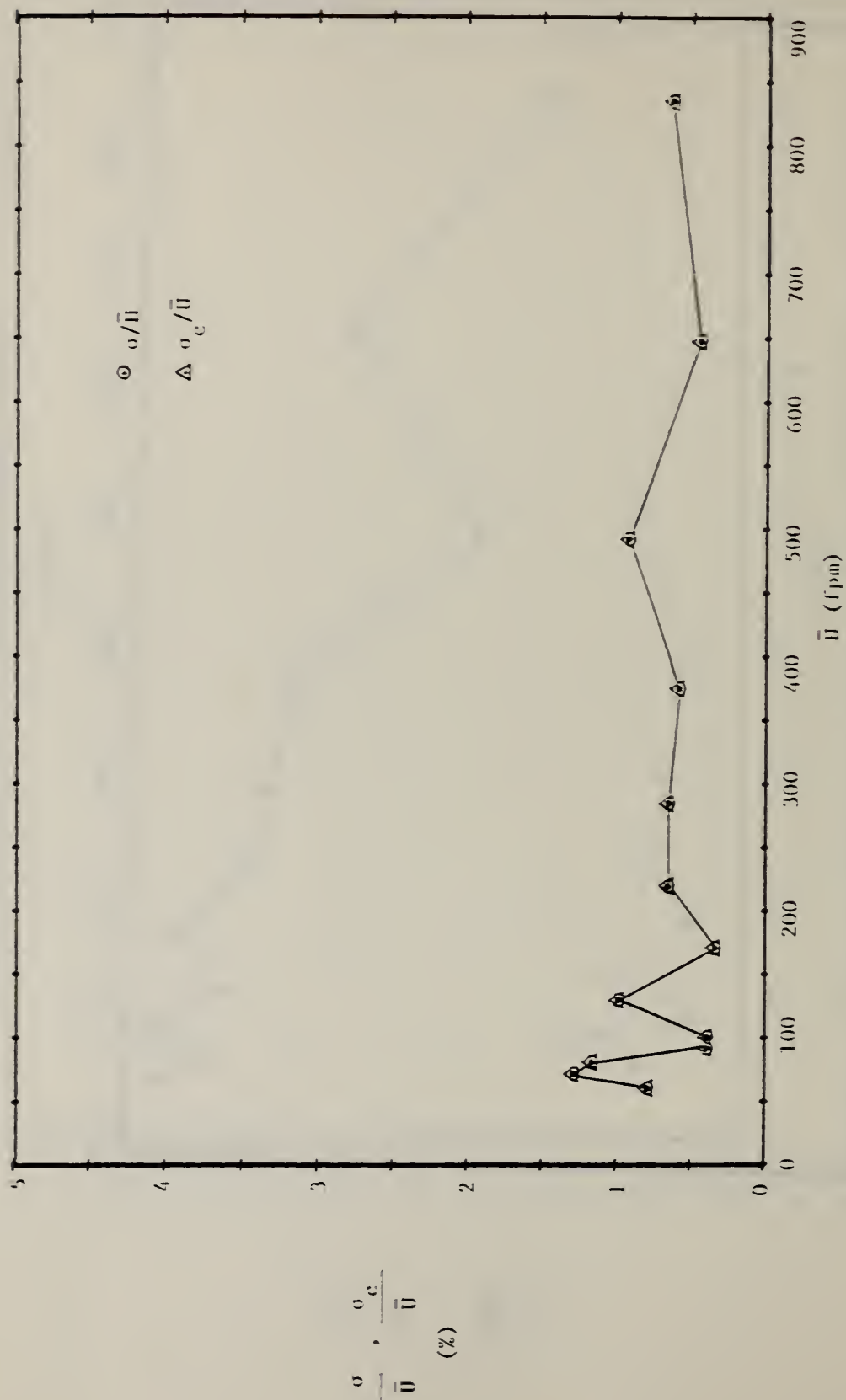


FIGURE 92.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY. INSTRUMENT II.

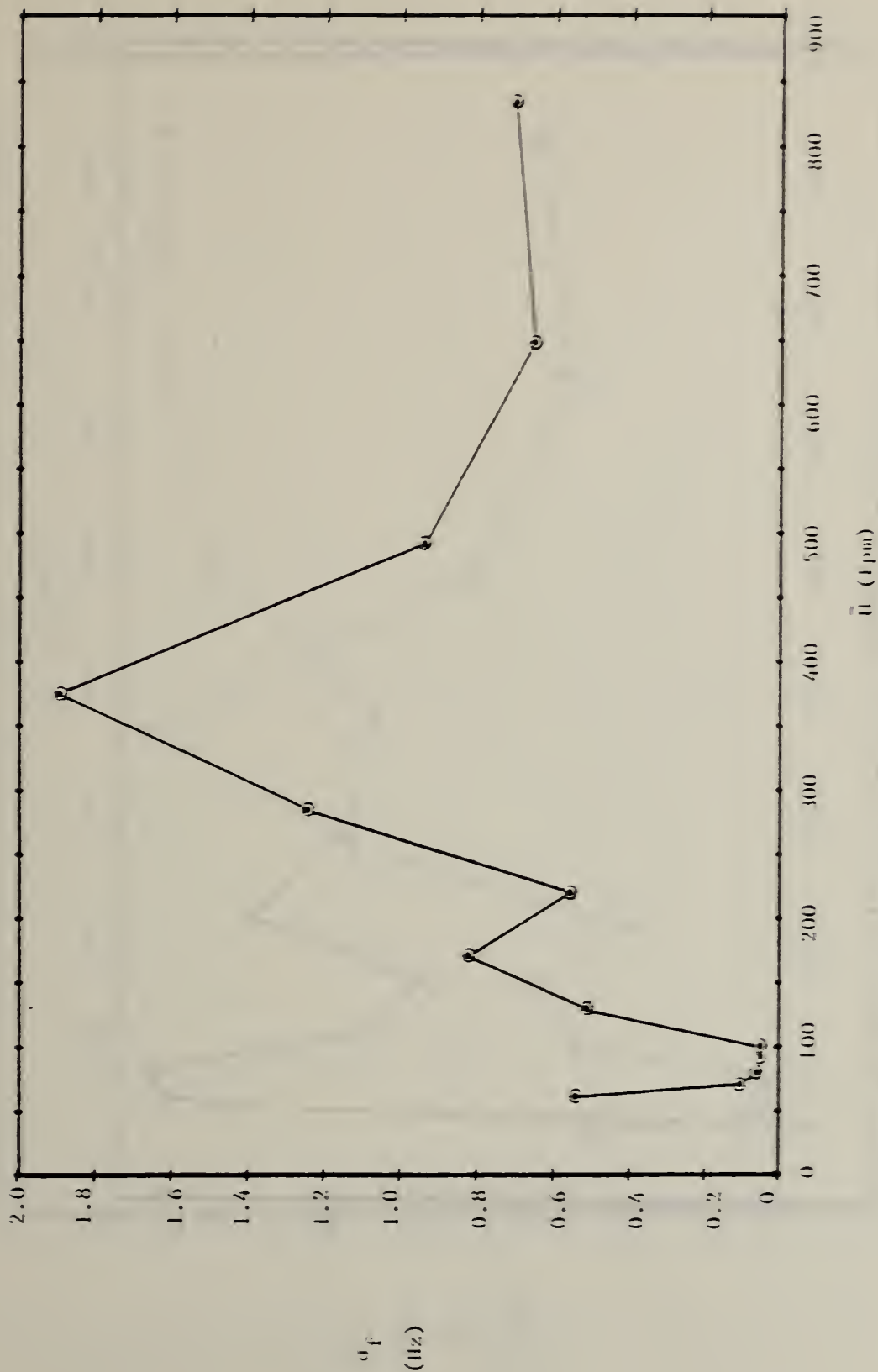


FIGURE 93. STANDARD DEVIATION OF PULSE FREQUENCY. INSTRUMENT 1.

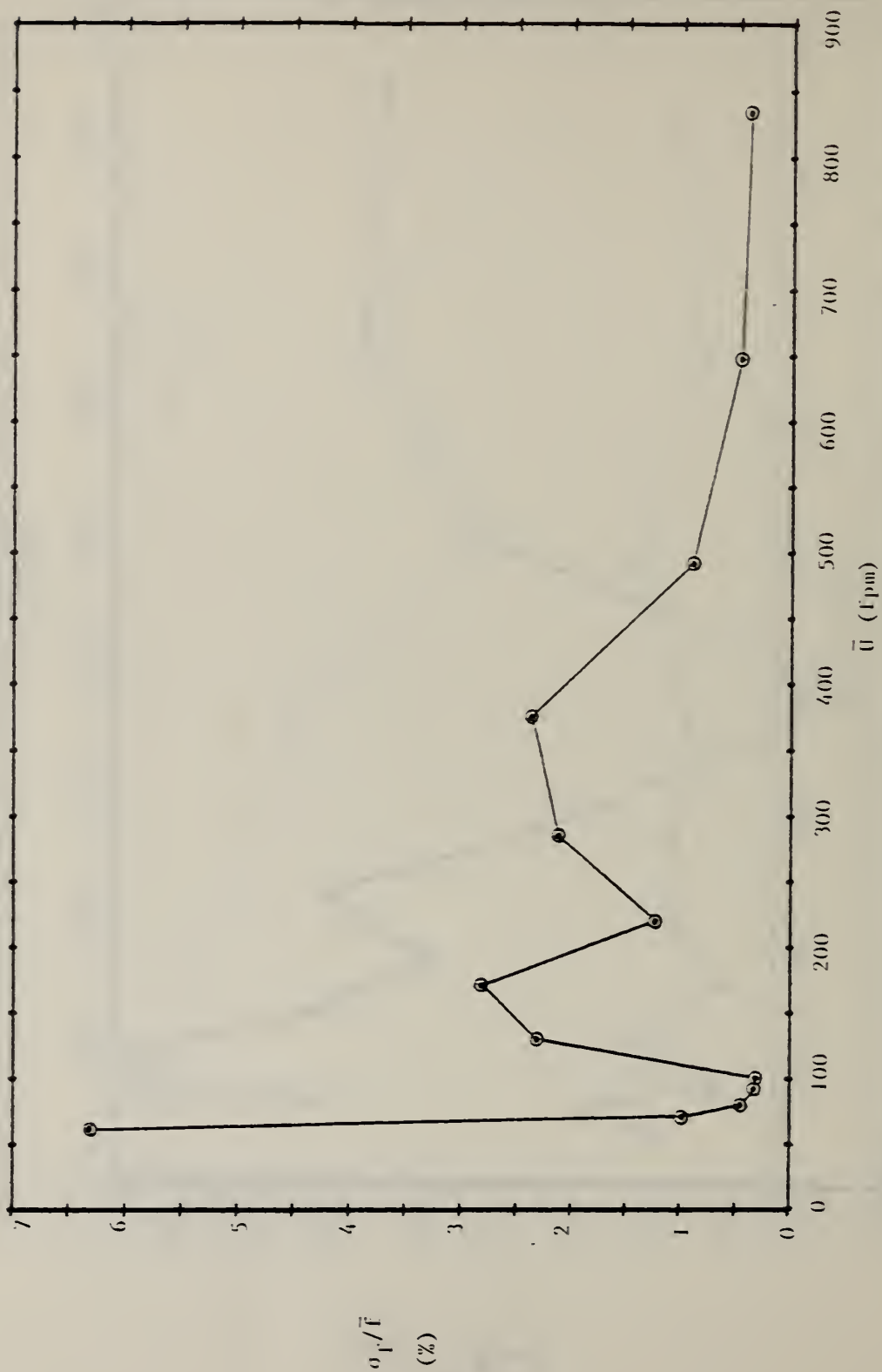


FIGURE 94. STANDARD DEVIATION OF PULSE FREQUENCY AS PERCENT OF GROUP MEAN FREQUENCY.  
INSTRUMENT I.

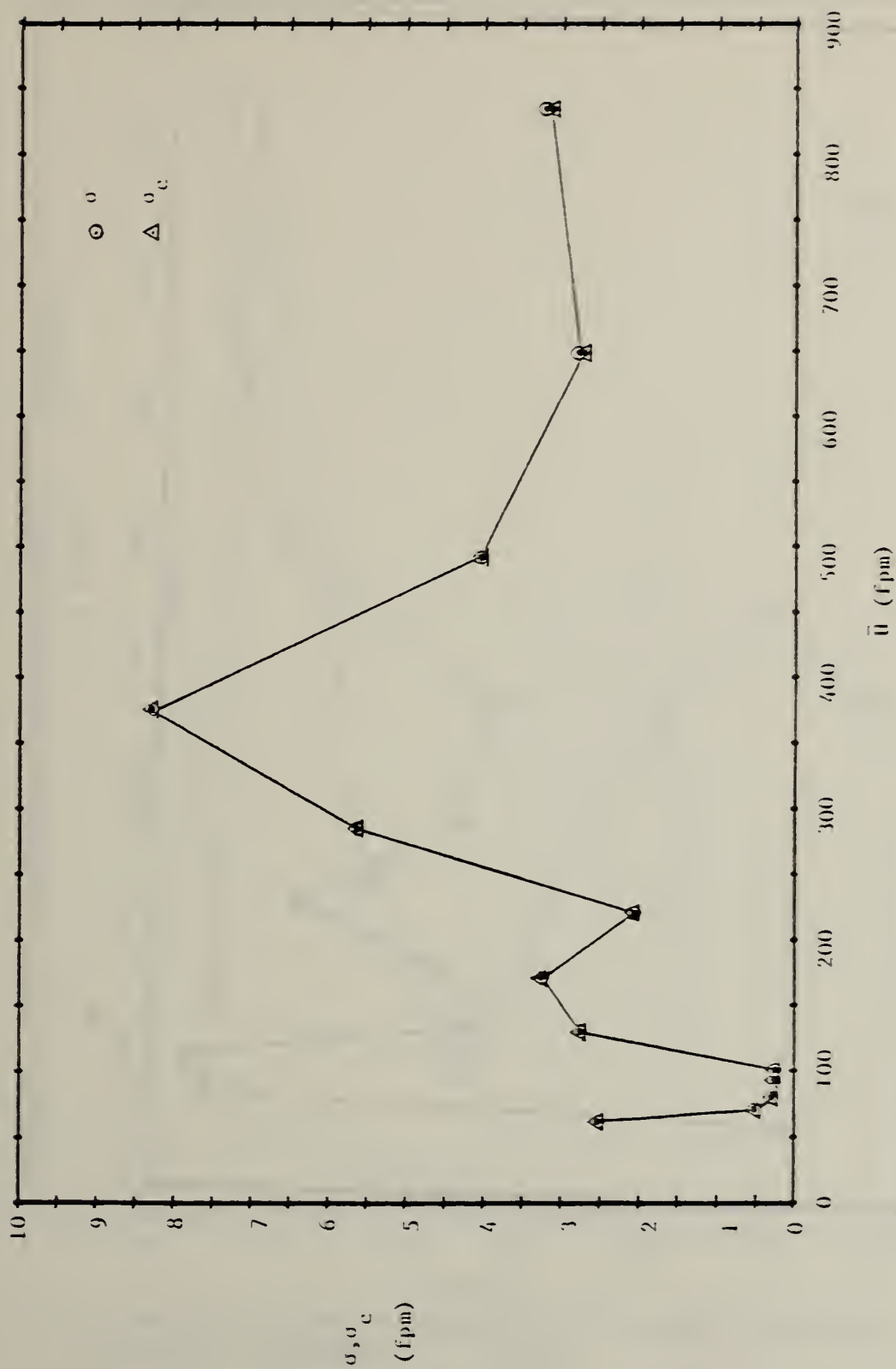


FIGURE 95. STANDARD DEVIATION,  $\sigma$ , AND CORRECTED STANDARD DEVIATION,  $\sigma_c$ , EXPRESSED AS EQUIVALENT TRUE VELOCITY. INSTRUMENT 1.

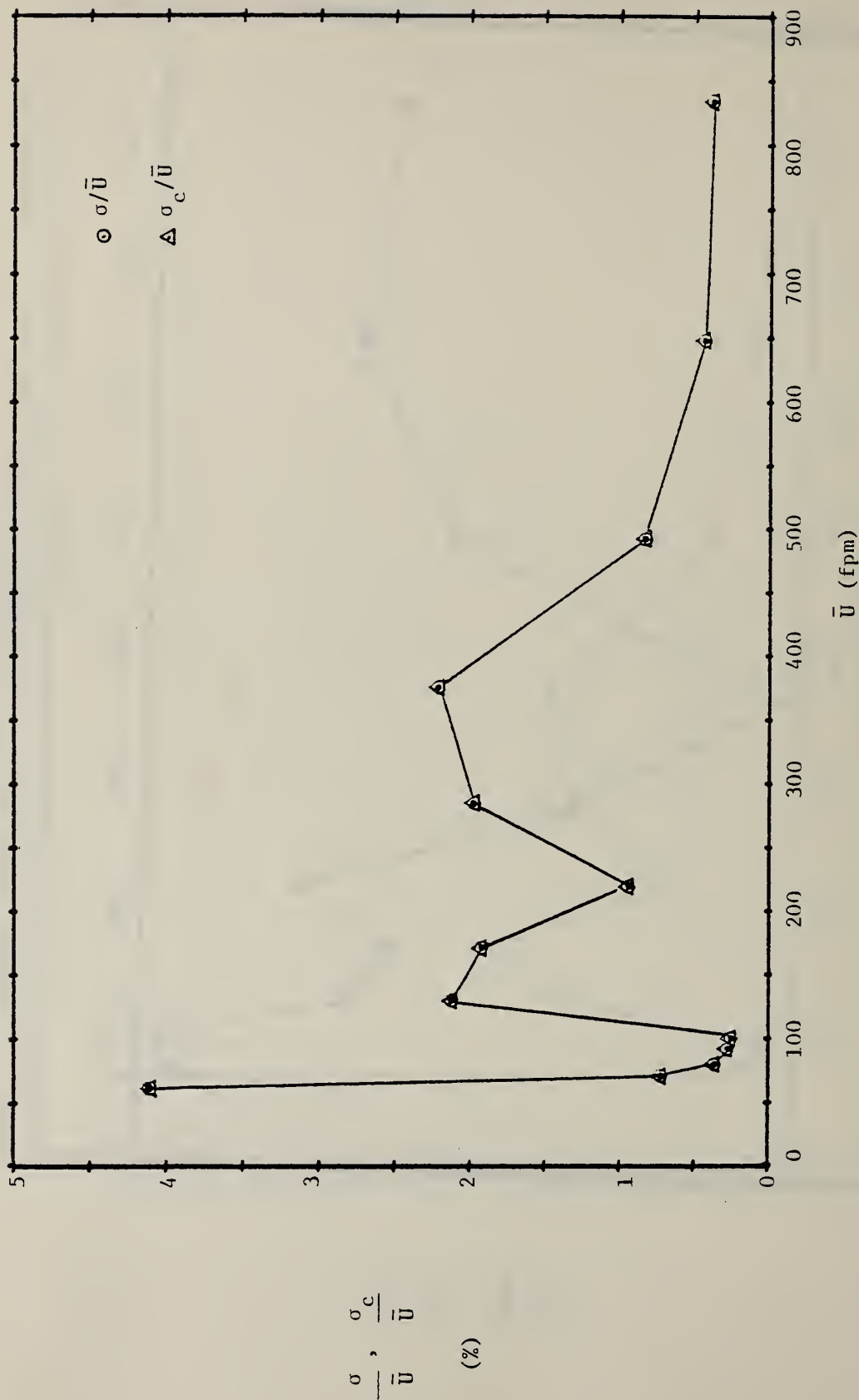


FIGURE 96.  $\sigma$  AND  $\sigma_c$  AS PERCENT OF GROUP MEAN VELOCITY. INSTRUMENT I.

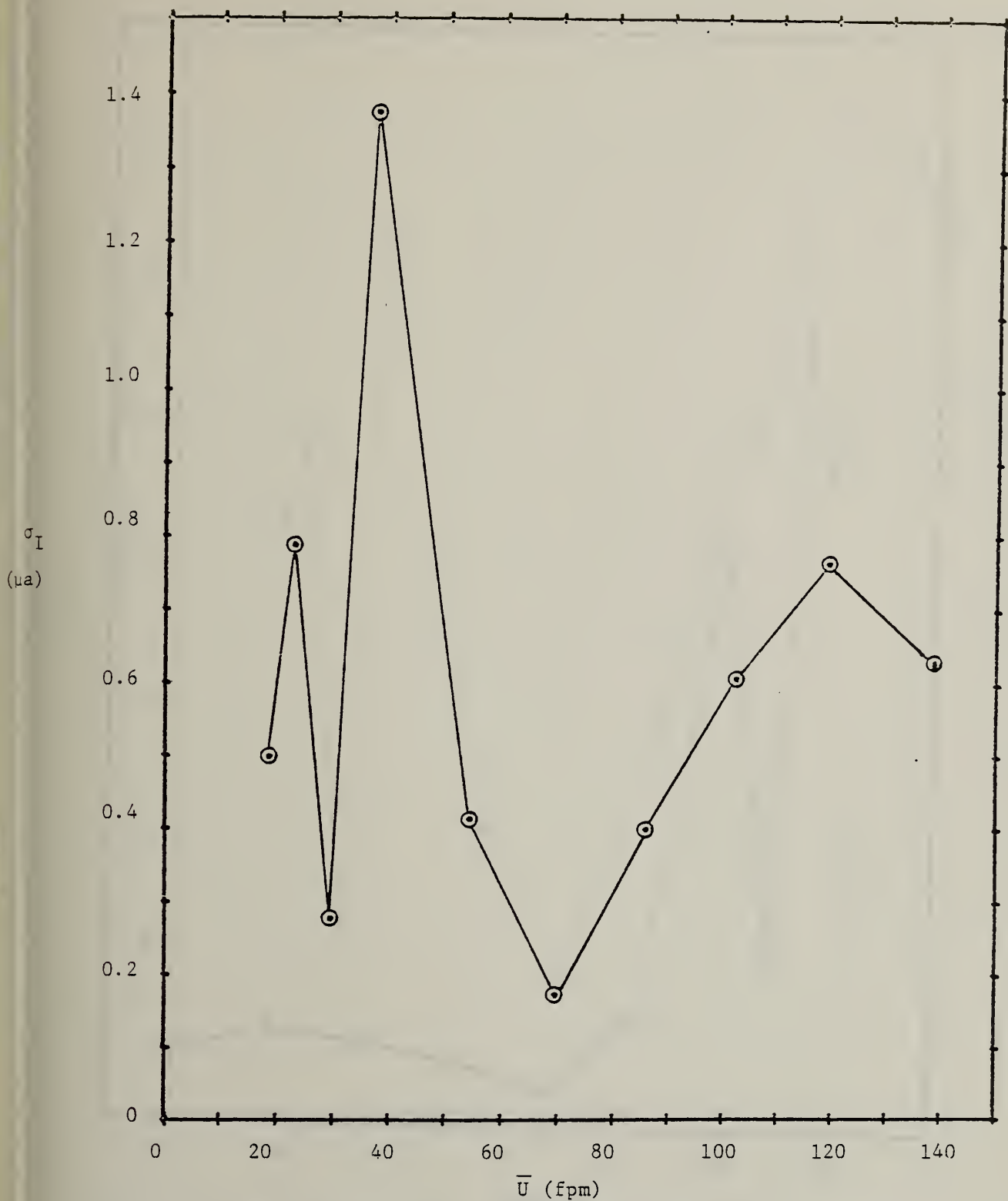


FIGURE 97. STANDARD DEVIATION OF INSTRUMENT OUTPUT AGAINST GROUP MEAN VELOCITY. INSTRUMENT J.

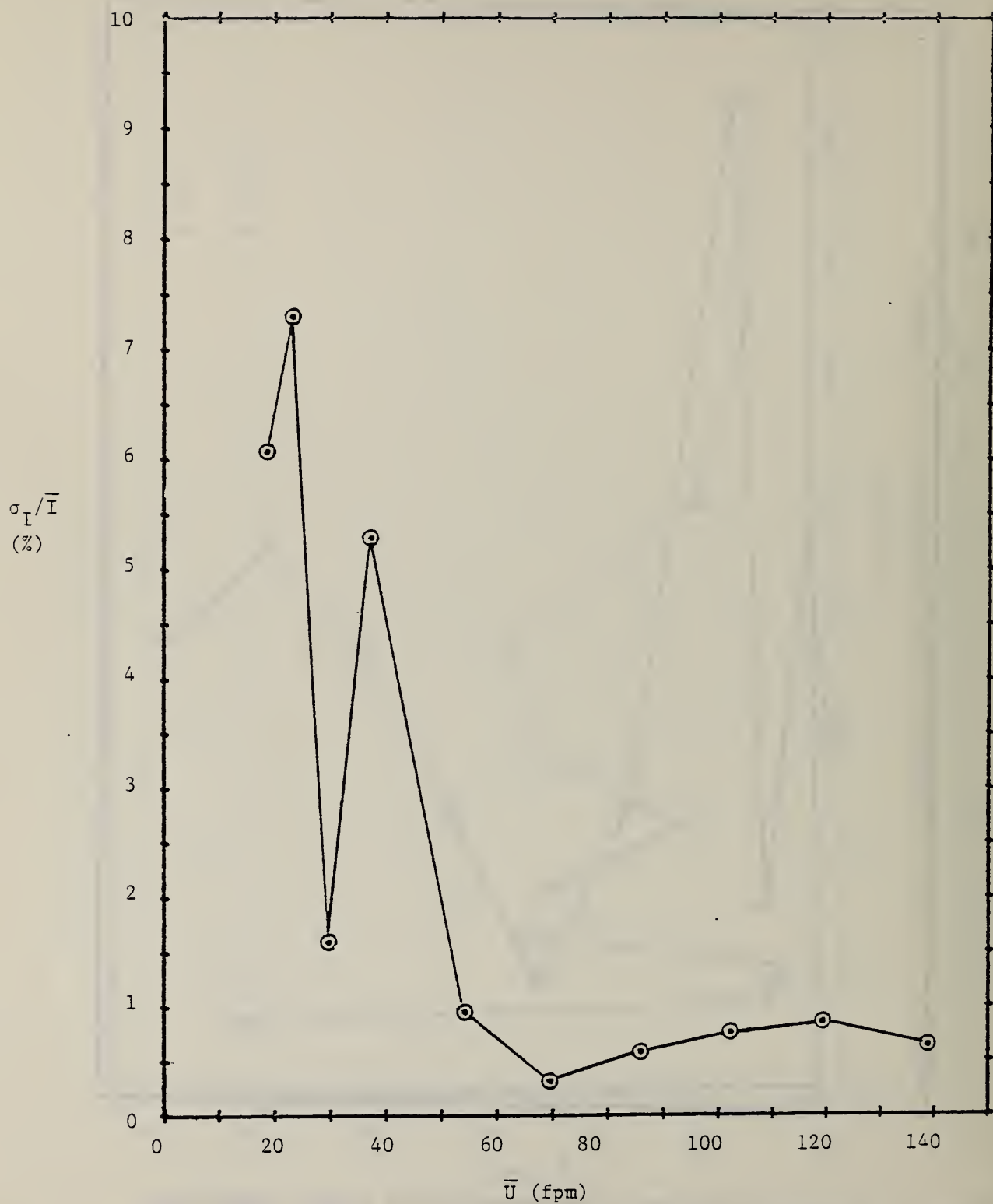


FIGURE 98. STANDARD DEVIATION OF INSTRUMENT OUTPUT AS PERCENT OF INSTRUMENT OUTPUT. INSTRUMENT J.

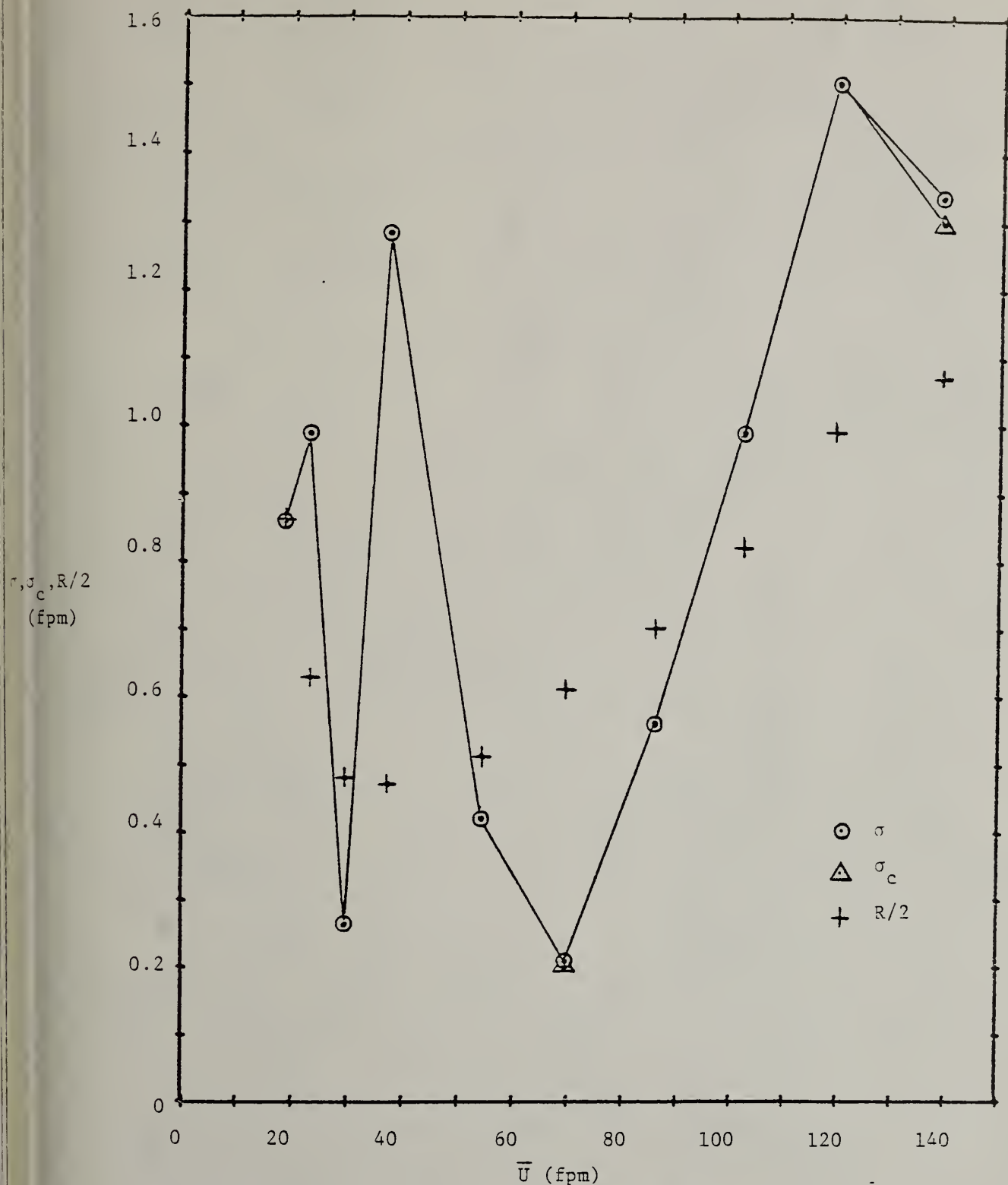


FIGURE 99. STANDARD DEVIATION AND CORRECTED STANDARD DEVIATION IN TERMS OF VELOCITY.  $R/2$  NOTED. INSTRUMENT J.

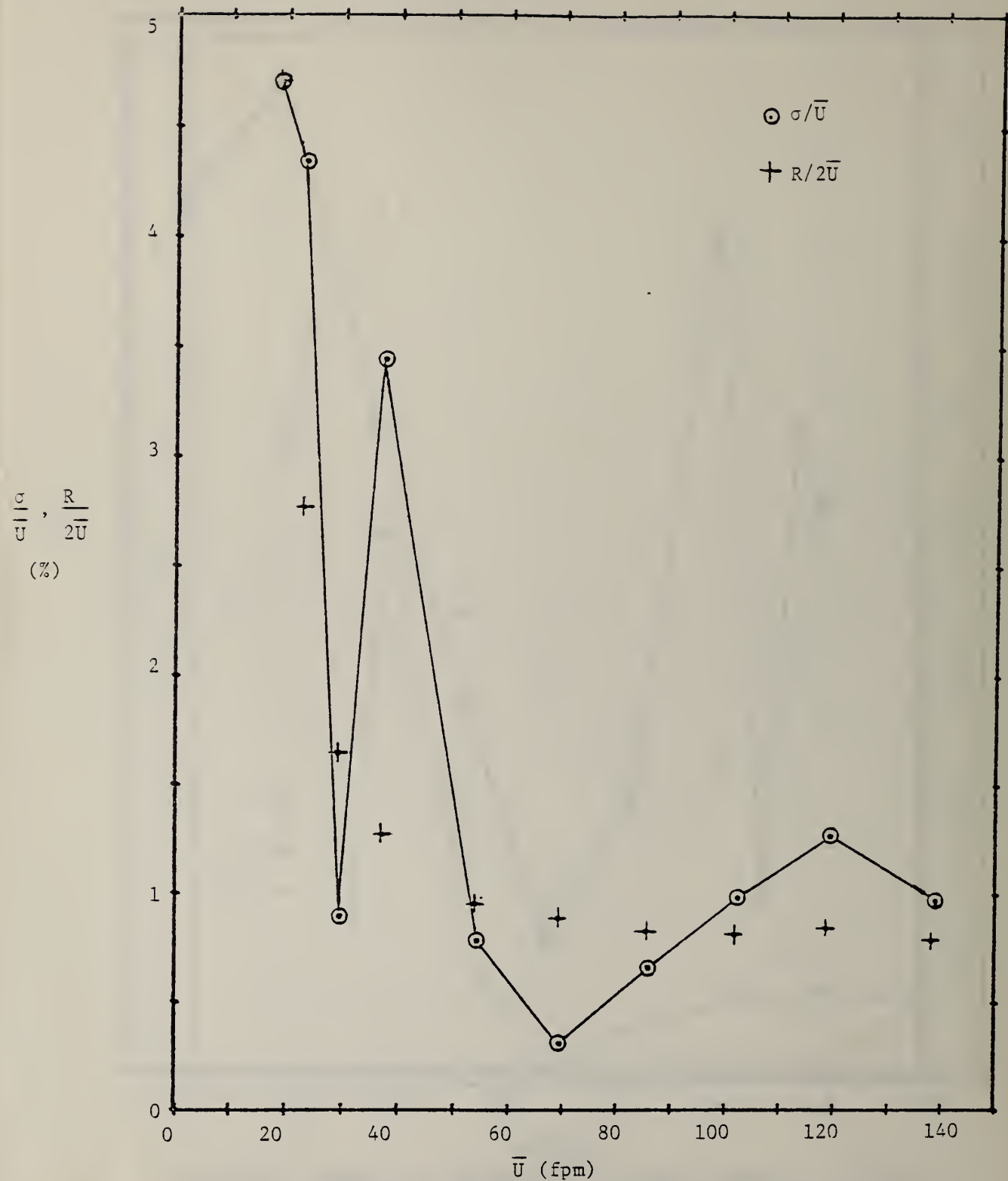


FIGURE 100. STANDARD DEVIATION IN TERMS OF VELOCITY AS PERCENT OF GROUP MEAN VELOCITY.  $R/2\bar{U}$  NOTED. INSTRUMENT J.